Weatherwise

ALMANAC ISSUE

Volume 13 · Number 1

FEBRUARY 1960

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE"—BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

DAVID M. LUDLUM, *Editor* HENRY W. BULKLEY, *Associate Editor*

AMS Elections

Dr. Thomas F. Malone, Director of Research for The Travelers Insurance Companies, Hartford, Conn., has been elected President of the American Meteorological Society for the two-year term of office, 1960–61.

Announcement of the Society's newly elected officers and councilors was made at the annual business meeting, concluding the four-day 40th Anniversary Meeting at the Somerset Hotel, Boston, January 19–22.

Patrick D. McTaggart-Cowan, Director of the Canadian Meteorological Service, with headquarters in Toronto, Ont., Canada, will serve as vice president, 1960–61.

Prof. James M. Austin will fill the office of Secretary for the one-year term, 1960. Prof. Austin is associated with the Department of Meteorology at Massachusetts Institute of Technology and is also Director of the Summer Session.

Re-election of Henry DeC. Ward as Treasurer for 1960 completed the selection of officers as voted by members of the Society.

Five councilors are elected each year by the Society's members for the three-year term of office. For 1960–62, the following will serve:

Robert C. Bundgaard, Lt. Colonel, USAF, Scientific Services Officer, 4th Weather Wing, Colorado Springs, Colo.;

Dr. Earl G. Droessler, Program Director for Atmospheric Sciences, National Science Foundation, Washington, D. C.;

Jerome Namias, Chief, Extended Forecast Section, U. S. Weather Bureau, Washington, D. C.;

Dr. Walter Orr Roberts, Director, High Altitude Observatory, University of Colorado, Boulder, Colo.;

Prof. Jerome Spar, Department of Meteorology and Oceanography, New York University, New York, N. Y.

Joseph A. Browne, Assistant Director of Meteorology, Trans World Airlines, Kansas City, was selected by the Council of the Society to fill the vacancy in the Council created by the election of Prof. James M. Austin as Secretary.

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Front Cover: Data supplied by the Office of Climatology, U. S. Weather Bureau.

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1959—A Year of Growth

SVERRE PETTERSSEN, *President, American Meteorological Society*

ANOTHER good year has passed and the Society may look forward to the future with confidence in continued health and sound growth.

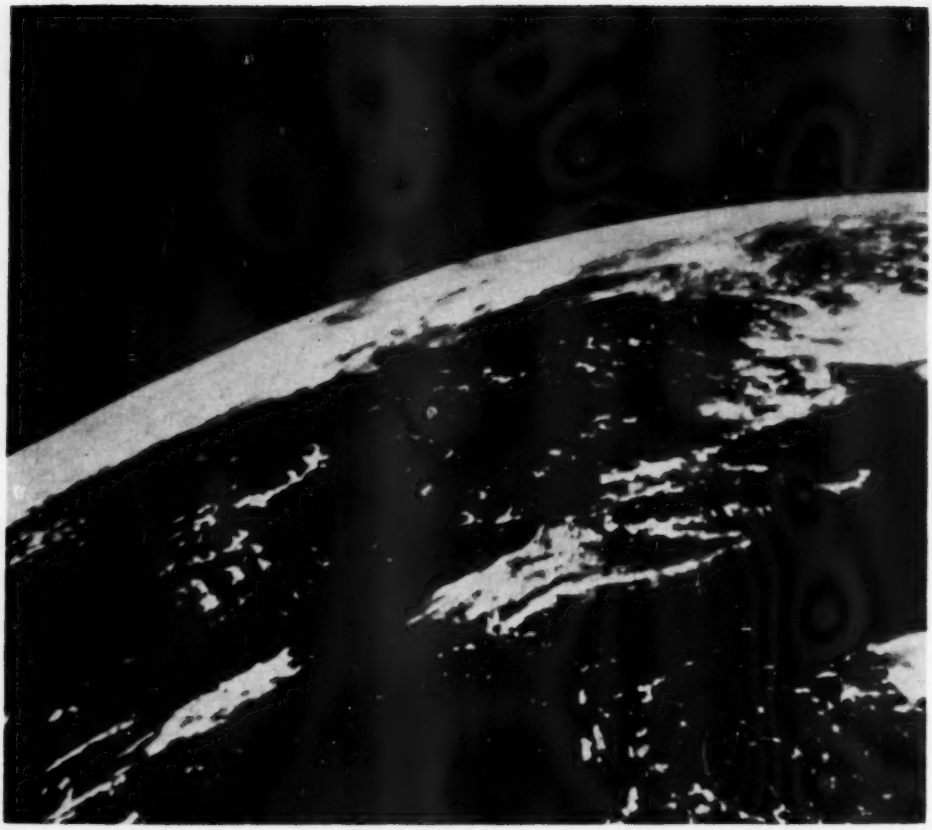
1959 was a good year not because of improvement in our financial situation, but rather because our capital of skill and know-how became well invested; it is all placed in the development of useful and important services to the profession and the nation.

The time has come for us to lift the science of meterology out of a state of neglect and place it on a level of prominence amongst the other physical sciences. We can achieve this by creating in wider circles an awareness of the importance of the multitude of scientific problems that the atmosphere has to offer; they range all the way from the grass-roots through the troposphere, the stratosphere, the ionosphere, and further to the tenuous border toward empty space. The problems are not only within the realm of physics; there are interesting atmospheric problems in chemistry, dynamics, mathematics, etc., and there are rich fields for students with engineering interests.

We live in a world which has become increasingly technological and, at the same time, highly competitive in a political sense. In this world we find that our chance of success is intimately connected with progress in science. In earlier years man was concerned with altitude; now he is concerned with distance from our planet and the possibility of entering outer space with a safe return. But the possibilities here depend very greatly on the development of new knowledge about the atmosphere and its changes. It is for this reason that meteorology has merited promotion to a level of prominence. The young student of today will do well to become acquainted with the varied opportunities that meteorology has to offer.

On the whole the plans and actions to

President Sverre Petterssen presents Flight Safety Foundation-Aviation Week Award to Vice President Henry T. Harrison at Honors Night, 40th Anniversary Meeting.



MOTHER EARTH FROM 700 MILES UP. A 2,000-mile strip of the Earth's surface as photographed from an Atlas Missile on 24 August 1959. In the foreground lie the islands of Hispaniola and Puerto Rico with the land mass of South America in the background. Scattered cloud areas appear over the ocean with more extensive layers over land. Official U. S. Air Force photo.

promote interest and progress in meteorology have followed the lines that I described in the February issue of *Weatherwise* a year ago, and it suffices here to indicate what has been added in 1959.

It will be recalled that fourteen universities with strong interests in meteorological research formed a committee to survey the field and prepare a plan for a National Institute for Atmospheric Research. During the year this committee developed into the University Corporation for Atmospheric Research (UCAR). Plans for a national research institute have been developed, and the National Science Foundation has obtained funds which will enable UCAR to begin work on the creation of the Institute. The thought is that the Institute shall serve not only as an intellectual center but also as the generous custodian of such research facilities as may be required to cope with intricate atmospheric problems. Many of these facilities are of such a nature that even first-rate universities cannot be expected to provide them. It is realized that large-scale electronic computors, a variety of electronic probing devices, flying laboratories, rockets and satellites are about to be added to the already long list of meteorological research equipment.

While UCAR works on the establishment of a national research center, the Society has undertaken to help solve the manpower problem. Young talent is urgently needed and the Society has set out to stimulate interest

in the atmospheric sciences amongst young students. The plans and hopes which I described in *Weatherwise* a year ago have taken more definite forms, and we may now speak of active, or almost active, projects. Of special interest are the following:

1. Our program for visiting lecturers to colleges and universities has been continued and expanded. At the time of writing over one hundred educational institutions are included and it is hoped that this service will assist many interested students to find their way into the study of atmospheric sciences.

2. A new program for visits of outstanding foreign scientists to centers of meteorological teaching and research has been organized. Each year about six such scientists will be invited and it is hoped that all institutions with advanced programs in meteorological research and teaching will take advantage of this service.

3. Funds are being sought for a plan to provide visiting lectures to high schools with science programs. In this manner we hope that a large number of high school students will become interested in atmospheric problems before they plan their further education.

4. During the summer of 1959 a pre-college science center was operated in cooperation with Loomis Preparatory School, and plans are underway for the operation of such centers each summer. The purpose here is to reach a relatively small number of especially gifted students so early that their plans for college education may be influenced. Though the courses are in the general sciences, there is a strong leaning toward atmospheric problems.

5. Plans are underway to produce about a dozen interest-stimulating monographs on various atmospheric subjects, and it is expected that these will enjoy wide distribution in high schools as well as colleges.

6. The Society will produce booklets on career opportunities in meteorology. These will contain all the information needed by students, career-guidance counsellors, teachers and parents.

7. Since meteorology is made up of a large number of basic sciences, inter-disciplinary activities are of particular importance. The Society has an active program for inter-disciplinary conferences, and in arranging these it collaborates with other societies in the United States and abroad.

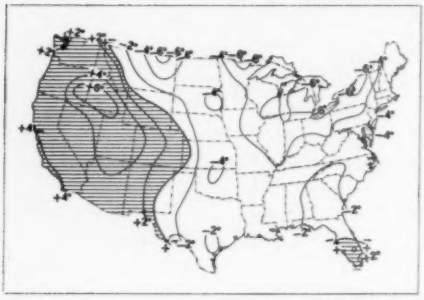
8. By far the largest program in meteorological education is the one concerned with the production of a series of meteorological motion pictures and slides. Funds are now being sought for this project and it is hoped that it will become active in 1960. The purpose here is partly to stimulate interest amongst young students and partly to provide instructional material for meteorological schools. Many of the meteorological phenomena occur on such unusual scales that they cannot be adequately represented in text books. It is for this reason that motion pictures are of particular importance in meteorological teaching.

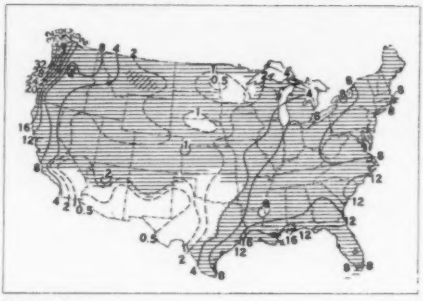
The Society and the meteorological profession are greatly encouraged by the National Science Foundation's vigorous program for atmospheric research and for their support of many of the projects mentioned above. Grateful thanks are due also to the Alfred P. Sloan Foundation and the Ford Foundation for their very generous fellowship programs. With all these aids and stimulants we may confidently expect that young talent will be attracted to the atmospheric sciences. Students who enter this field now should have no difficulty in finding fascinating work and good employment when they, in due course, emerge with a degree.

Prof. Tor Bergeron and wife, of Uppsala, Sweden, examine silver iodide generator for first time. Prof. Bergeron's classic paper, "On the Physics of Cloud and Precipitation," (1933), provided much of the theoretical background for modern cloud seeding. Location is an anti-lightning experiment of the Calif. Div. of Forestry in the Sierra Nevada, July 1959. (U. S. Forest Service photo.)

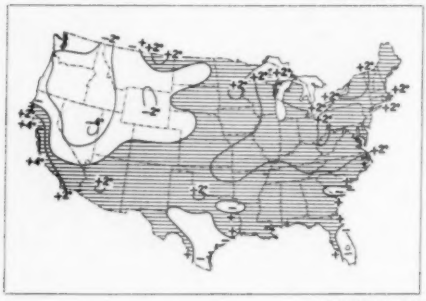
THE WEATHER BY SEASONS 1959

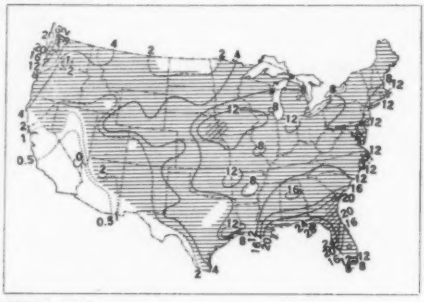
WINTER (DECEMBER–FEBRUARY) 1958–1959



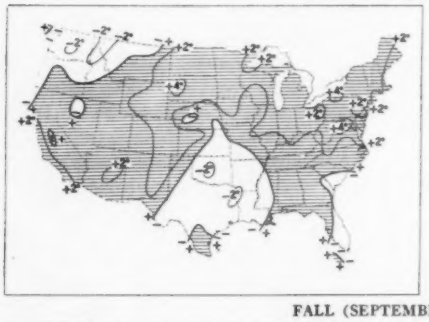


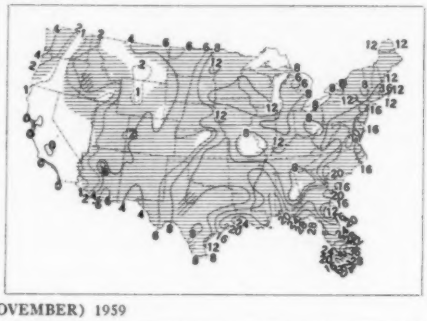
SPRING (MARCH–MAY) 1959



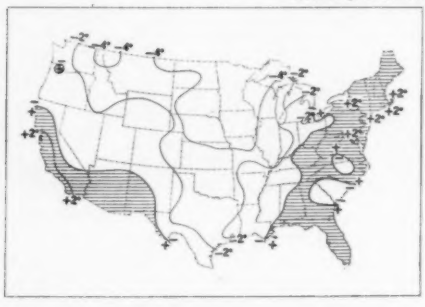


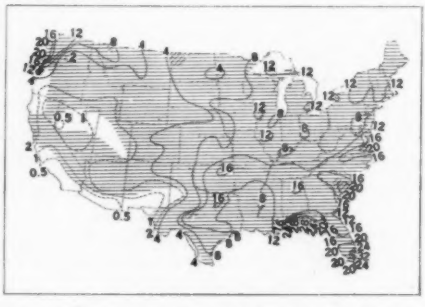
SUMMER (JUNE–AUGUST) 1959





FALL (SEPTEMBER–NOVEMBER) 1959





Charts show the departure of the temperature from normal in degrees Fahrenheit by seasons 1958. USWB charts.

Charts show the total precipitation in inches by seasons 1958. USWB charts.

The Circulation and Weather of 1959

WILLIAM H. KLEIN, *Extended Forecast Section,*
U. S. Weather Bureau, Washington, D. C.

WINTER

AN outstanding feature of this winter's circulation and weather over North America was extreme persistence from December 1958 to January 1959. During both months the mean circulation in mid-troposphere was characterized by deep troughs in the eastern Pacific and along the east coast of North America, separated by a strong ridge near the West Coast. The corresponding features of the mean pressure distribution at sea level, shown in figure 1 for January, included deep Lows in the Gulf of Alaska and near Newfoundland, a strong High in the Arctic Ocean north of Alaska, and weak Highs in the Great Basin and southeastern Pacific.

The dashed arrows in figure 1 represent the principal path of migratory polar anticyclones at sea level. Numerous daily Highs originated in the Arctic Ocean or northwest Canada and moved southeastward through a ridge of high pressure into the northern Plains and the Southeast. Each High was accompanied by a fresh outbreak of cold Arctic air which quickly overspread all portions of the United States east of the Continental Divide, where surface temperatures averaged well below normal during December and January. At Muskegon, Mich., the mean temperature during each month was the lowest on record. By way of contrast, temperatures for December and January averaged well above normal from the Rocky Mountains to the West Coast because of strong onshore flow of mild Pacific air under a well developed ridge aloft.

The solid arrows in figure 1 represent the principal track of migratory cyclones at sea level during January. Several daily Lows entered the Pacific Northwest, moved southeastward across the Rockies, redeveloped in the central Plains, and then traversed the Lower Lakes, enroute to Newfoundland. Considerable precipitation fell along this track, with monthly totals ranging up to 200 per cent of normal in Kansas, the Ohio Val-

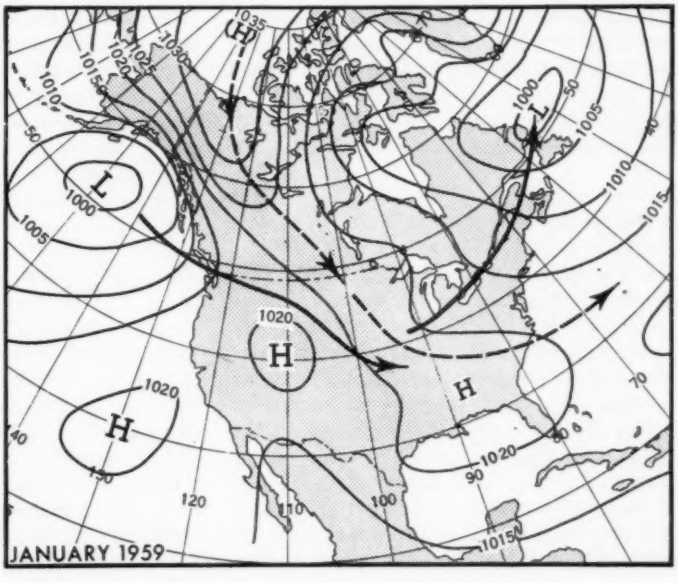


FIG. 1. Mean sea level isobars (in millibars) for January 1959. Dashed arrows represent principal track of migratory anticyclones responsible for frequent outbreaks of cold air east of the Continental Divide. Heavy solid arrows indicate main path of daily cyclones and accompanying band of heavy precipitation.

ley, and the Pacific Northwest. Snowfall was unusually heavy from the central Plains to the Great Lakes region. South of the principal storm track dry sunny weather prevailed, with less than 25 per cent of normal precipitation in much of the Southwest.

During February 1959 the large-scale circulation underwent a dramatic reversal from the persistent state of the previous two months. Trough conditions replaced a strong ridge in the western United States, while mean ridges developed over the Southeast and in the eastern Pacific. At the same time the mean jet stream was displaced southward over the western and central United States but northward in the rest of the Western Hemisphere. As a result general warming occurred in the eastern half of the country, and marked cooling ended the West's warm regime.

Development of the mean trough in the West was accompanied by the outbreak of considerable precipitation in the southwest quadrant of the United States during February. Heavy amounts along the Gulf and South Atlantic coasts were produced by persistent southwesterly winds which lifted moist Gulf air over the polar front. Somewhat similar conditions prevailed in Montana, where the Arctic front was overrun by moist Pacific air. Above-normal precipitation and floods in the Ohio Valley were associated with recurrent confluence and cyclone passages. Dry conditions prevailed in the central Plains and southern Rockies due to downslope effects, and from the southern Appalachian northeastward to New England due to post-trough desiccation.

Spring

Departures from normal of 700-mb height for March were rather small over much of the contiguous United States. Over the Western States above-normal heights were associated with a mean ridge along the coast. In the Eastern States weak negative anomalies over a broad band were typical of a flat mean trough. The mean flow of small amplitude across North America was accompanied by zonal trajectories of the daily Highs at sea level. The continental polar anticyclones glanced east-southeastward, affecting only the northeastern United States, where monthly surface temperature averaged a few degrees below normal. The remainder of the country was dominated by maritime Pacific air masses which produced mild weather in the northern and central Plains but slightly below normal temperatures in the South and Pacific Northwest.

Precipitation over the United States during March was fairly well related to the mean vertical motion for the month, as approximated for the mid-troposphere in figure 2. A large area of descending motion (negative values) in the southwest quadrant of the United States limited precipitation to less than 25 per cent of normal. Figure 2 also shows descending motion in the northern Great Plains, where this month was among the driest Marches on record at numerous stations. Large values of ascending motion in the extreme Southeast were accompanied by heavy rains, with monthly totals ranging up to 400 per cent of normal in Florida. In the Northwest above normal precipitation occurred with mean upward vertical motion and faster than normal west-southwesterly flow across the mountain range. Heavy precipitation also fell in a band of mean ascending motion along a principal cyclone track from the central Great Plains to the Great Lakes. Dubuque, Iowa, reported its greatest March accumulation of both liquid precipitation (6.5 inches) and total snowfall (30.2 inches) since records began in 1851.

The circulation pattern at the 700-mb level during April resembled that which had prevailed during March and the first two months of the winter season. Once again a mean trough was located in the eastern Pacific, a mean ridge near the west coast of North America, and a broad trough in eastern North America. As a result of this persistence in circulation, some sizable departures from normal of precipitation were accumulated from December 1958 to April 1959, as depicted in figure 3. The most striking anomaly was in the Southwest, where a vast area from Texas to southern California received less than half of normal precipitation during the 5-month period. Abundant sunshine acompanied the dry weather, with Ely, Nev., and Sacramento, Calif., experiencing their sunniest April on record. Persistent subsidence and northerly flow in a stronger than normal upper-level ridge just off the West Coast were largely responsible for the dry regime.

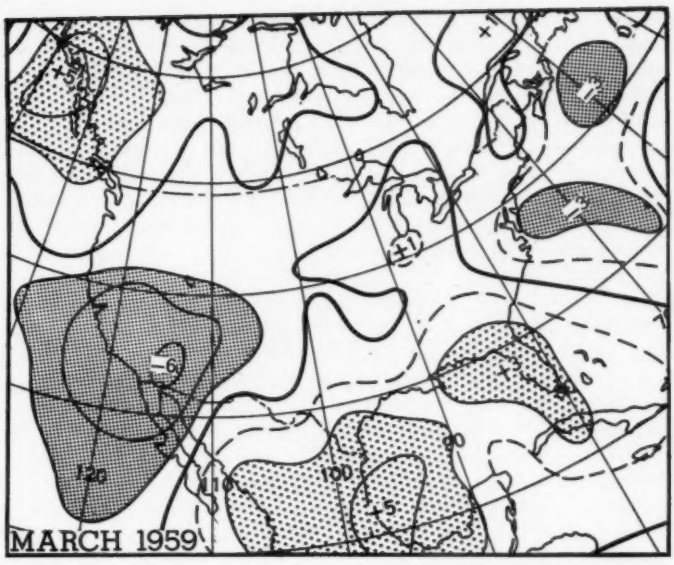


FIG. 2. Mean vertical motion at the 600-mb level in millimeters per second for March 1959 with descent negative and ascent positive. Map was obtained by averaging values computed twice-daily on an operational basis by the Joint Numerical Weather Prediction Unit in Suitland, Md. Isoline interval in 2 mm/sec. and absolute values greater than 2 are stippled.

Figure 3 shows that another area of long-period precipitation deficiency was found in northern portions of the Great Plains and Mississippi Valley. Duluth, Minn., had its driest January–April period in 88 years of record. Most of this deficit was a function of stronger than normal northwesterly flow to the rear of the mean trough in eastern North America. In addition, the primary storm tracks passed both north and south of the drought area. Along the southern track a narrow band of heavy precipitation extended from the central Rockies through Nebraska to the Great Lakes. Heavy precipitation also occurred along the Gulf and South Atlantic coasts, mostly as the result of overrunning of cool polar air masses in southwesterly flow aloft. Lakeland, Fla., reported an all time April precipitation record of 8.48 inches, with the January–April total of 28 inches also a record for the period.

The circulation pattern over the United States underwent a drastic reversal from April to May, as a deep mean trough ap-

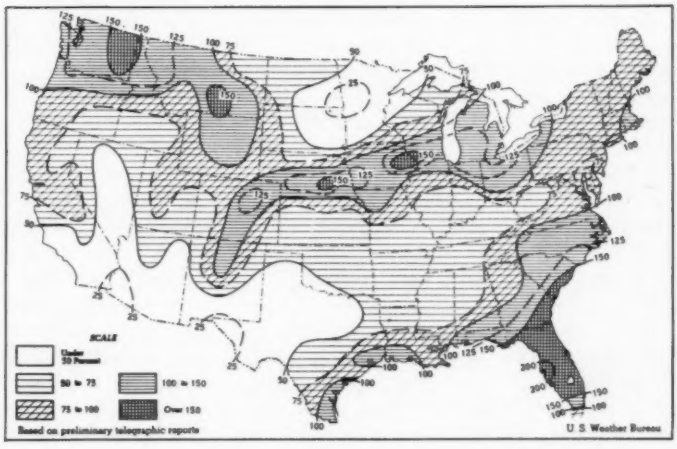


FIG. 3. Percentage of normal precipitation for the 5 months from December 1958 to April 1959. Note prolonged period of dryness in Southwest and northern Plains.

peared in the West and a strong mean ridge developed in the East. A corresponding reversal occurred in the temperature regime (fig. 4A). Marked cooling to *below* and *much below* normal took place over a broad area west of the Continental Divide, where temperatures had averaged above normal during April. In the eastern two-thirds of the United States temperatures increased from near normal during April to *much above* normal in May.

The marked frontal system which separated polar Pacific air masses in the West from tropical Gulf air in the East led to widespread cyclonic activity and precipitation. Monthly totals ranged up to 200 per cent of normal in a belt extending from the southern Plains to the upper Mississippi Valley, with near-record amounts at several points in western Iowa and eastern Nebraska. In the Southeast this May was also among the wettest of record, with frequent heavy showers and thunderstorms and a large contribution from tropical storm Arlene. In the Southwest, conversely, continued dry weather aggravated the existing drought situation. Tucson, Arizona, reported its driest January through May period since records began in 1868; while Wichita Falls, Texas, experienced its 10th consecutive month with subnormal precipitation. New England and the Middle Atlantic States were also relatively dry under the influence of anticyclonic offshore flow; and Hartford, Conn., and Scranton, Pa., reported their driest May of record.

Summer

Another reversal of circulation and temperature patterns took place over the United States from May to June, as illustrated in figure 4B. The deep cold trough over the Western States in May was replaced by a warm ridge in June. Conversely, in the eastern United States extensive blocking led to substantially reduced temperature anomalies. Abnormal warmth in the Southwest was attended by high percentages of possible sunshine, and new records were established for both elements at several stations.

The temperature pattern for May (fig. 4A) had favored vigorous development of storms along the frontal boundary separating cool air in the North and West from warm air in the East and South. Just the opposite was indicated in the temperature pattern for June (fig. 4B), with warm air in the Northwest and cool air in the Southeast. As a result June's precipitation was of the local shower, summer variety. A broad belt of southeasterly flow from the Gulf of Mexico provided adequate moisture for orographic rainfall in the mountainous regions of New Mexico, Arizona, and Utah and for locally severe thunderstorms in the central Plains. A streak of above normal precipitation from Texas northeastward through Arkansas occurred in conjunction with a weak mean trough at 700-mb in that area. Several tropical disturbances produced heavy rains along the Gulf Coast and damaging tornadoes in Florida. Excessive rainfall in the North Atlantic States could be attributed to blocking of Lows over New England. Persistent easterly winds produced 24 cloudy days at Portland, Maine, to equal the alltime record for any month. Rainfall was almost nonexistent in much of California, Arizona, and Nevada, where weak westerlies and above normal 700-mb heights prevailed in a zone of diffluence. Phoenix, Ariz., reported its eighth consecutive month with below-normal precipitation; while Sacramento, Calif., recorded its driest March–June period in 110 years of record.

During July many of the troughs and ridges on the mean 700-mb map were out of phase with those on the normal chart. The common situation in summer is for a continental anticyclone to persist over central United States, but during July 1959, a 5-day mean trough was located in this area over half the time, as illustrated in figure 5. Likewise ridges were unusually frequent in eastern and western coastal areas, where troughs are normally found.

This abnormal circulation resulted in cool, wet weather in cyclonic 700-mb flow over most of the central United States. In parts of Texas, Kansas, Nebraska, and Missouri temperatures averaged below normal every week. Few extratropical cyclones were observed in this area, and most rainfall resulted from heavy local showers and hurricane Debra. Another major area of precipitation was centred over the Middle Atlantic States, where moisture-laden tropical air masses predominated in southeasterly flow. Much of the rainfall was associated with cold and

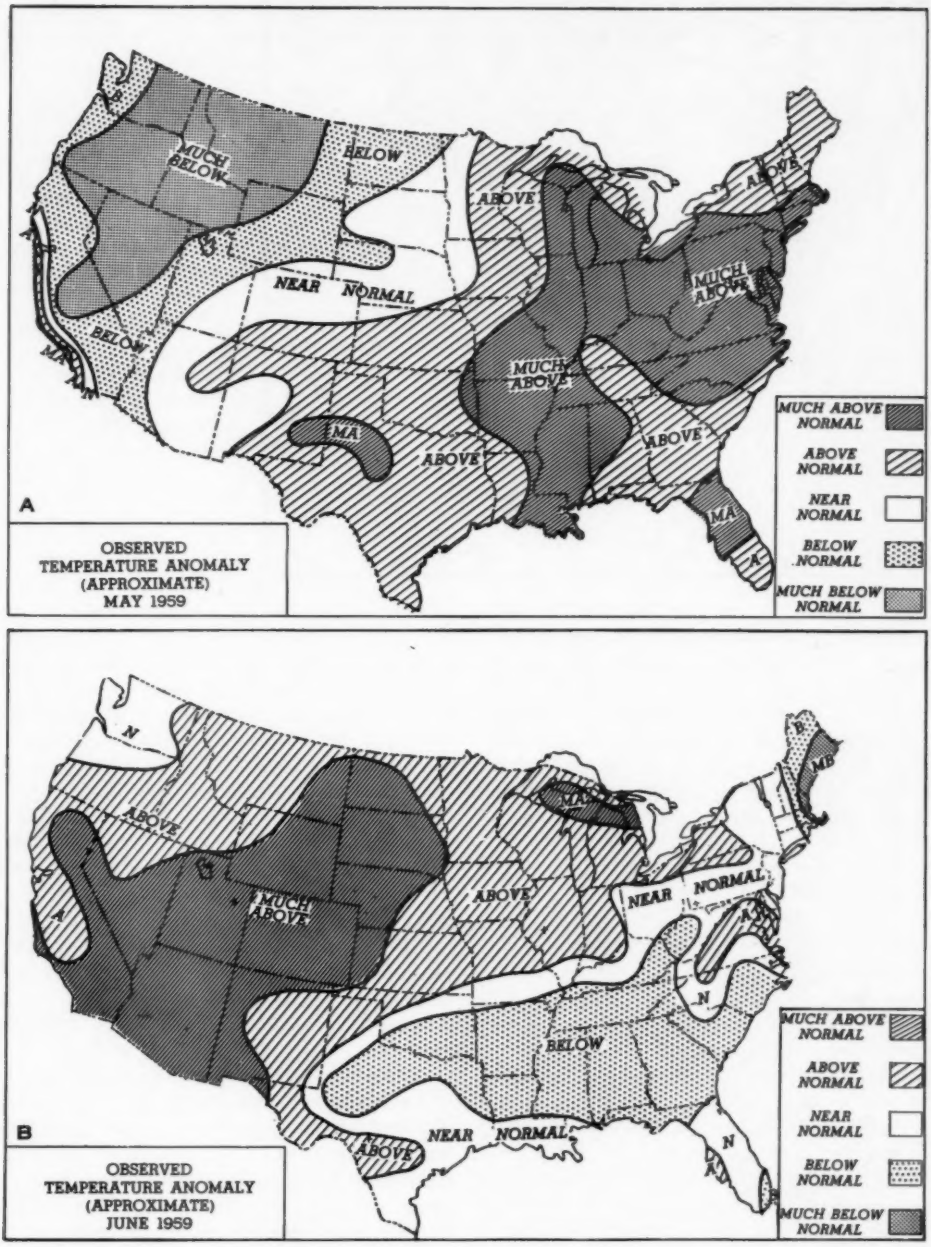


FIG. 4. Mean surface temperature departure from normal expressed in terms of 5 classes for (A) May and (B) June, 1959. Normal is based on the 30-year period 1921–1950, with the classes above, below, and near normal each occurring one-quarter of the time and much below and much above one-eighth of the time.

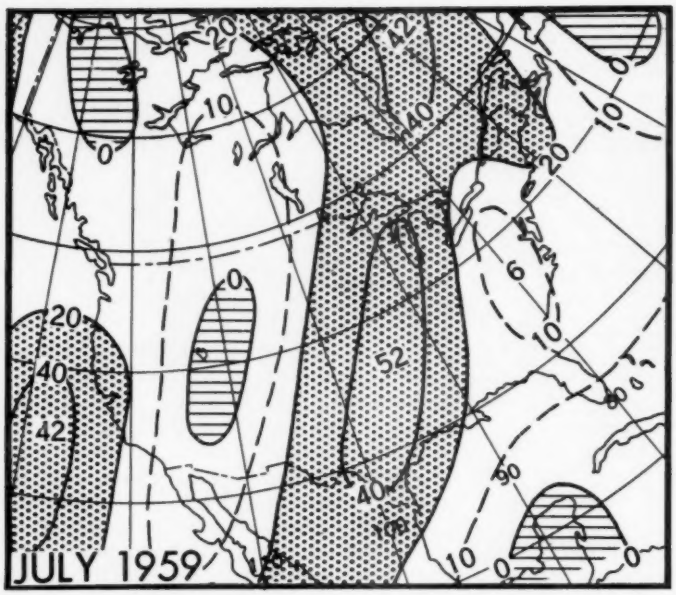


FIG. 5. Per cent of the time that troughs on 5-day mean 700-mb charts were located within 10° longitude intervals at latitudes from 20°N to 70°N during July 1959. Frequencies greater than 20 per cent are stippled and zero areas are hatched. Troughs were located in the central U. S. as much as 52 per cent of the time.

stationary fronts which were located in this sector more than half of the days during July, but hurricane Cindy also contributed. Atlantic City, N. J., had 15.69 inches of rain, the greatest on record for any month. New England was north of the anomalous easterly flow and therefore predominantly warm and dry under a mean ridge aloft. Warm and dry weather also prevailed west of the region of frequent 700-mb troughs. A broad band of little or no rainfall extending from California northeastward to Montana was associated with persistent anticyclonic circulation and dry, northerly anomalous flow at 700-mb. This circulation was responsible for a record heat wave in parts of California and Arizona and record dryness at many stations in the Rocky Mountain States.

August 1959 was an exceptionally hot month for most of the United States. In about three-quarters of the country monthly temperatures averaged warmer than the seasonal normal, and cooler than normal weather was confined principally to a patch in the southern Plains and a belt extending from the Pacific Northwest to parts of the southwestern desert. Greatest departures were observed in the northeastern quarter of the nation, where temperatures averaged from 2 to 6 degrees above normal. A composite chart prepared from 10 previous months with heat waves in this quadrant closely resembled the 700-mb mean chart observed during August 1959 (fig. 6). Typical heat-producing features of figure 6 were the strong ridge in the eastern Pacific, the deep trough in western North America, and the flat ridge in the eastern United States. Of particular importance was the belt of fast westerlies across Canada, where absence of the normal ridge precluded advection of cold air into the eastern half of the U. S. In the latter area the extensive tropical ridge and broad southerly flow at sea level induced recurrent thrusts of warm Gulf air.

Accompanying the heat wave was a regime of high relative humidity, largely as a result of low-level transport from tropical maritime source regions. The availability of moisture favored widespread convective showers and contributed to a surprisingly liberal distribution of heavy rainfall in many portions of the heat wave zone. Another area of heavy rainfall was found in the Pacific Northwest, where faster than normal westerly flow in the mean trough produced as much as 3 times the normal amount. East of the Continental

Divide, however, the westerlies introduced foehn drying. In Montana and Wyoming observed precipitation totals were less than 25 per cent of the monthly normal. Glasgow reported that August was its sixth consecutive month with below normal precipitation, and Billings recorded its driest May through August since 1894.

Fall

The circulation pattern over North America during September 1959 was similar in many respects to that for August shown in figure 6. Heights at the 700-mb level remained above normal in the Atlantic coastal ridge and the eastern Pacific High and below normal in western Canada. However, a double trough structure developed in the western U. S., one along the Pacific coast and one to the lee of the Rockies. Generally below normal heights in the West were accompanied by lower than normal surface temperatures in cool Pacific air masses. On the other hand, the Northeast, the Mississippi Valley, and the southern Plains averaged warmer than normal. To illustrate the contrast, it was the warmest September on record at Binghamton, N. Y., and the coldest at Idaho Falls, Idaho.

September was a wet month over most of the United States as a result of a strong influx of moist air from the Gulf of Mexico, Pacific, and Atlantic. Very heavy precipitation occurred in the West from Nevada northward, and many places in this region experienced their wettest September on record. Record amounts of snow fell in Colorado, where Colorado Springs received 28 inches during the closing days of the month. By way of contrast, very dry weather prevailed under the influence of the ridge aloft in the Northeast and downslope winds in the southern Plains.

During October and November a remarkably persistent and simple pattern of circulation and temperature became established over the United States, as illustrated in figure 7. During both months temperatures averaged well below normal from the Rockies to the Appalachians but above normal in the Southwest and Southeast. Numerous records for prolonged and severe cold were broken in mid-sections of the continent, where southward displacement of the jet stream and storm track induced repeated outbreaks of polar air from an unusually cold source region in central Canada (fig. 7).

The October–November circulation pattern is well illustrated in figure 8, the mean 700-mb map for November. The features of greatest importance to the United States were the stronger than normal trough in central North America and ridges along the West Coast and in the mid-Atlantic. Northerly anomalous winds (parallel to the dotted lines

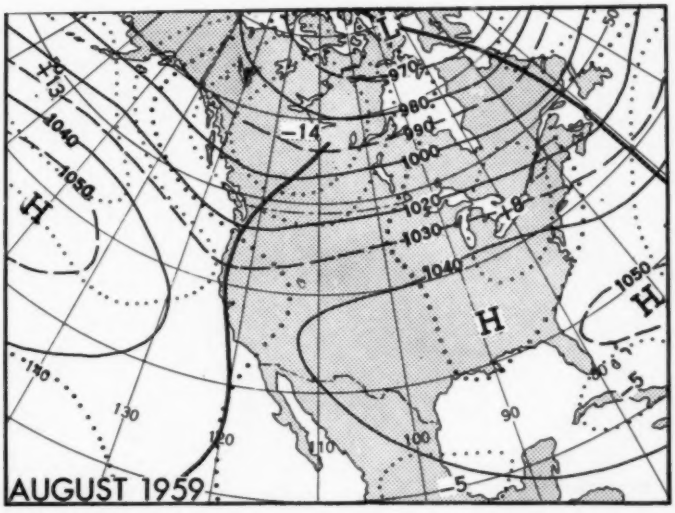


Fig. 6. Mean 700-mb chart for August 1959. The contours (solid) are labeled in tens of feet, with intermediate contours dashed. The lines of equal departure from normal 700-mb height are dotted and drawn for every 50 feet with anomaly centers labeled in tens of feet. Heat wave in the Northeast was associated with stronger than normal ridge in that area and deeper than normal trough (delineated by heavy vertical line) in western Canada.

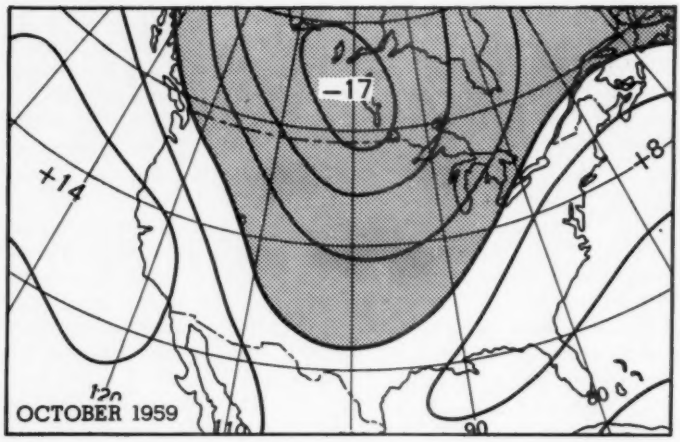


FIG. 7. Departure from normal of mean thickness of the layer from 1000 to 700-mb for October 1959. Isoline interval is 50 feet, centers are labeled in tens of feet, and subnormal values are stippled. The polar source region over central Canada and the northern Plains was abnormally cold.

of equal height departure in fig. 8) carried cold air from the Arctic to Texas, while southerly wind components provided abundant moisture for extensive precipitation from the Gulf of Mexico to the Northeast. During October precipitation exceeded or equalled normal in practically the entire United States except the Southwest. Frontal activity was especially pronounced along the mean boundary of the cold air, outlined by the zero line in figure 7. In addition, tropical storms Irene and Judith contributed additional downpours from Florida to North Carolina. During November precipitation diminished considerably in the southern half of the nation due to the absence of tropical storms and the appearance of a pronounced rain shadow in the Great Plains. Precipitation continued

(*Continued on page 40*)

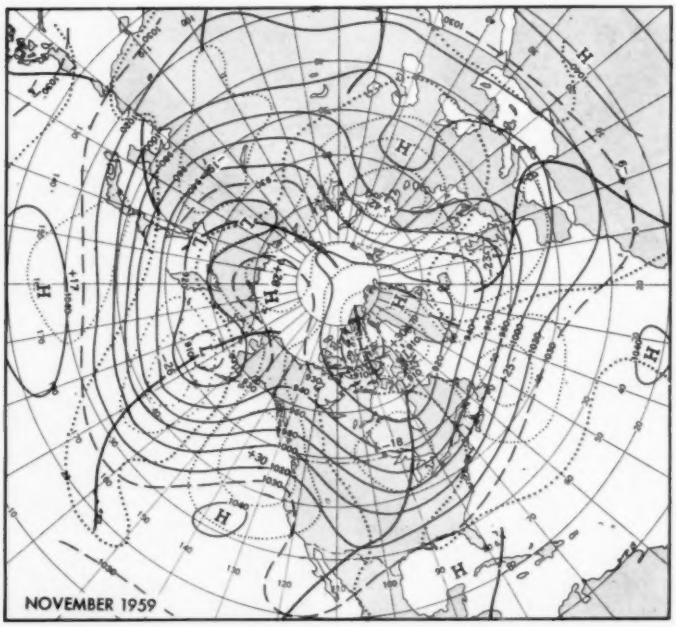


FIG. 8. Mean 700-mb chart for November 1959. The contours (solid) are labeled in tens of feet, with intermediate contours dashed. The lines of equal 700-mb height departure from normal are dotted and drawn for every 100 ft. with anomaly centers labeled in tens of feet. A well defined system of four sinusoidal waves extended around the Northern Hemisphere at middle latitudes.

Tornadoes During 1959

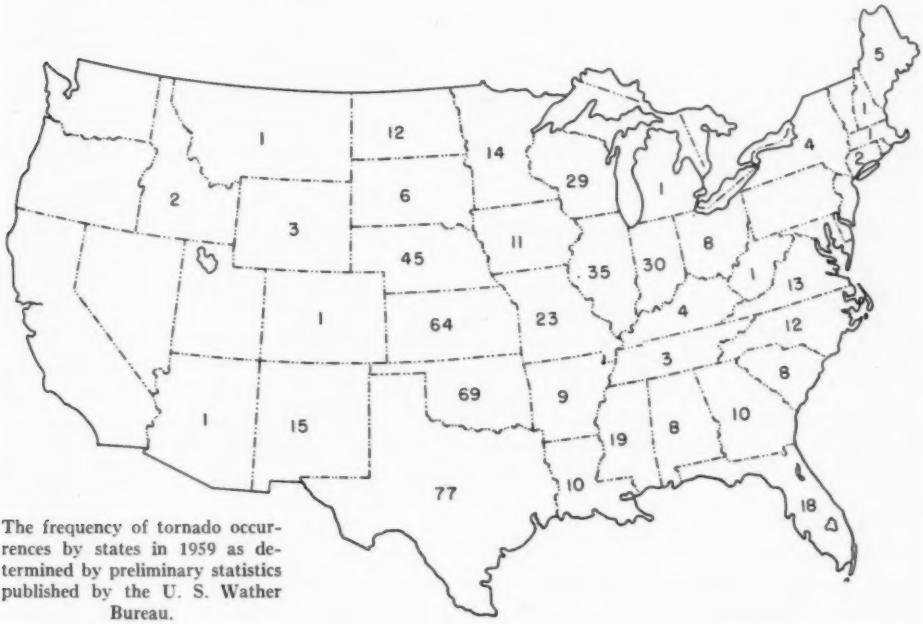
ROBERT G. BEEBE, *Midwest Weather Service, Kansas City, Missouri*

THE number of observed tornadoes in 1959 was not enough to make the devoted severe storm forecaster really happy. Using the publication, *Storm Data*, of the U. S. Weather Bureau, for the first 10 months of 1959 and unofficial reports for the final two months, a total of 580 tornadoes were reported. This figure is about 45 less than the previous year, and very sharply lower than the years between 1952 and 1957. Much of this, however, is due to a difference in classification as funnel clouds were not considered as tornadoes in the two past years. During 1959, 535 funnel clouds and 75 waterspouts were noted in addition to the tornadoes.

Last year the number of deaths attributed to tornadoes was down to only 58, the lowest number since 1951 and only about one-quarter of the average over the past 43 years. The total number of tornado-inflicted injuries was nearly 700, with about half of these caused by the February St. Louis tornado.

The number of tornadoes reported in each state in 1959 is shown on the accompanying map. In 1958, only six states did not report tornadoes, whereas in 1959 twelve states escaped the violence of tornadic winds including Alaska and Hawaii. It may be noted that Iowa, a state that in the past has reported nearly as many tornadoes as Kansas, shows sharply lower totals in 1959 as was true in 1958 also.

The first major tornado outbreak occurred on 21 January, striking the Southeastern states. Tornadoes in this area are likely to occur at any time of the day or night and the first reported funnel on the ground was in Alabama at 0545C. Later in the day, other tornadoes developed in Louisiana, Mississippi, Kentucky, Tennessee, and finally, the last one occurred at 2115E in North Carolina. Altogether, 13 tornadoes were reported, three persons were killed, and five others injured. Although no tornadoes were reported



The frequency of tornado occurrences by states in 1959 as determined by preliminary statistics published by the U. S. Wather Bureau.

Palm trees smash parked car during Miami's worst tornado since 1927. Storm occurred during a developing hurricane situation on evening of 17 June 1959. UPI photo.

in Georgia, extensive wind, rain, and electrical storms caused considerable damage there that afternoon over a 20-county area. In the only tornado reported in Louisiana, a woman was picked up on the back steps of her house carried around the house by the rotating wind, and finally deposited unhurt.

The most devastating family-type tornado outbreak developed, unseasonably, in southwestern Missouri on 9 February. The first reported tornado was in the Joplin area at 1410C. Some 8 hours later, around 2100–2200C, other funnels and a tornado were reported to the north and northeast of Joplin. Meanwhile, successive surface maps after 1500C showed a very small low pressure center (some analysists might term this a meso-low) moving to the east-northeast, towards St. Louis at 50 knots. The tornado (some investigators found evidence that several tornadoes occurred there) struck St. Louis at 0140C, 10 February, causing great destruction, killing 21 persons and injuring 347 more. The forward speed of this tornado across St. Louis County was estimated at 50–60 mph, or about the same as the mother low with which it was associated. Later that night and the next morning, numerous other tornadoes and funnels occurred in Illinois, Indiana, and Ohio with this same storm setting. At least 10 confirmed tornadoes were reported with this situation.

On the last day of March, an outbreak of seven tornadoes developed in the late afternoon in Oklahoma. The first tornado of this series was seen at 1655C in north central Oklahoma. Other tornadoes formed over Oklahoma a little later, and a group of three funnels wiped out the community of Silver City. There were numerous reports of hail from the size of golf balls to hen eggs north of Silver City. There were other tornadoes in Texas and Arkansas associated with this same storm setting and, in all, six lives were lost and over 60 others were injured.

One of the most unusual tornadoes of 1959 occurred at Miami, Florida on 17 June. A tornado with a forward speed of 25–30 mph moved into Miami from Coral Gables, a suburb just south of Miami, at 0950E and continued on a track 12 miles long before moving out to sea. Although property damage was around $3,000,000 and 77 people were injured, no one was killed. This was the most severe tornado in Miami in over 30 years. Another tornado developed just north of Miami with this same synoptic situation but fortunately did not strike the populated areas.

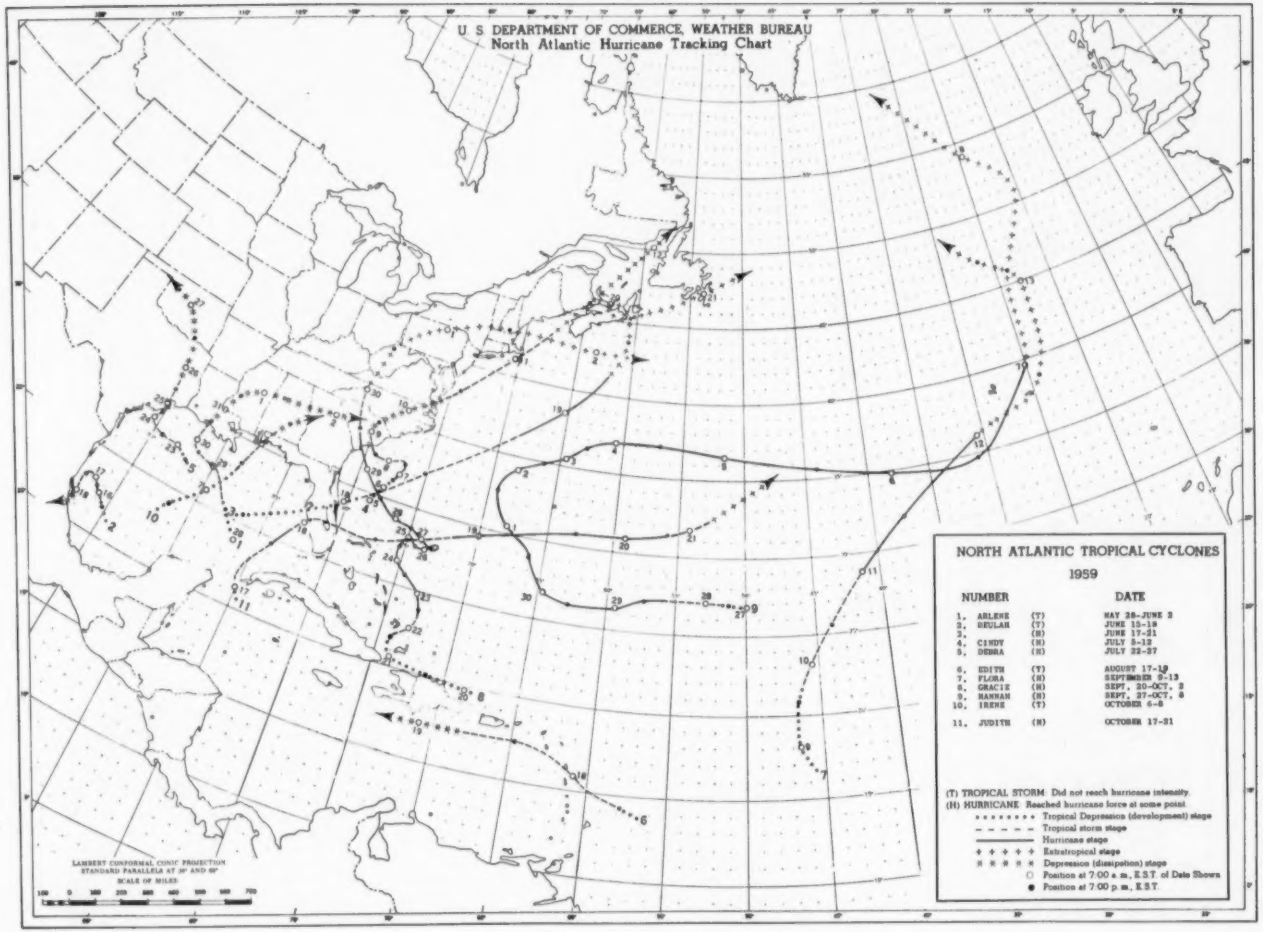
The last death-dealing tornado outbreak of the year struck in Virginia on 30 September. During the later afternoon, three tornadoes caused extensive damage near Charlottesville, snuffing out 12 lives and injuring 13 other

persons. Eleven people were killed in one building.

Tornado research was at a slower pace in 1959 than before but will be sharply increased in the spring of 1960. The Weather Bureau, cooperating with the U. S. Air Force, the National Air Space Agency, the Office of Naval Research, the Federal Aviation Agency and other government groups, will be embarking upon an extensive research program. It is currently planned that the P-38 flown by Jim Cook, three airplanes from the National Hurricane Research Project, and possibly others will be probing tornado forecast areas with special instrumentation. It is also planned that rockets will be sent up, on request, to take photos of squall lines and tornado-bearing clouds; serial radiosonde ascents will be made; and other special instrumentation will be probing the tornado's secrets. The aircraft instruments will be measuring temperature, humidity, wind direction and speed, turbulence, and other meteorological parameters. This will be at least a three-year project for the purpose of learning more about the environment of the air mass in which tornadoes develop.

HAIL STORM IN JUNE OVER KANSAS

An aerial view of hail stones 18 inches deep covering ground at Selden in northwestern Kansas on 3 June 1959. A sustained fall of small hail for 85 minutes produced the scene. Hail area measured about 9 miles from northeast to southwest and 6 miles across at widest with Selden near the center. Dark area in background shows fields beyond the hail area. Damage was estimated at $500,000. Photo courtesy of the *Norton Daily Telegram*.


U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU
North Atlantic Hurricane Tracking Chart
LAMBERT CONFORMAL CONIC PROJECTION
STANDARD PARALLELS AT 30° AND 60°
SCALE OF MILES
NORTH ATLANTIC TROPICAL CYCLONES
1959
NUMBER
DATE
1. ARLENE (T) MAY 28-JUNE 2
2. BEULAH (T) JUNE 15-19
3. (H) JUNE 17-21
4. CINDY (H) JULY 8-13
5. DEBRA (H) JULY 22-27
6. EDITH (T) AUGUST 17-19
7. FLORA (H) SEPTEMBER 9-13
8. GRACIE (H) SEPT. 30-OCT. 2
9. HANNAH (H) SEPT. 27-OCT. 8
10. IRENE (T) OCTOBER 6-8
11. JUDITH (H) OCTOBER 17-21
(T) TROPICAL STORM Did not reach hurricane intensity
(H) HURRICANE Reached hurricane force at some point
Tropical Depression (development) stage
Tropical storm stage
Hurricane stage
Extratropical stage
Depression (dissipation) stage
Position at 7:00 a. m., E.S.T. of Date Shown
Position at 7:00 p. m., E.S.T.

The Hurricane Season of 1959

WALTER R. DAVIS, *Weather Bureau Office, Miami, Florida*

THE hurricane season of 1959 in the Atlantic-Carribean-Gulf of Mexico area was about normal, with the occurrence of eleven tropical cyclones (fig. 1). During the past two to three decades, the average occurrence has been ten cyclones. With the exception of hurricanes Gracie and Hannah, the average intensity was rather weak. Cindy, Debra, Flora, and Judith barely reached hurricane intensity. Tropical storm Beulah almost reached hurricane intensity with winds estimated 70 mph by reconnaissance aircraft. An unnamed weak depression came out of the Gulf of Mexico in mid-June, became entangled with a frontal system in the Atlantic off the U. S. East Coast, and developed winds of hurricane intensity.

The first storm developed in May, an early season beginning and a rarity for this section of the world. Activity continued on the high side during June and July, then practically ceased during August and early September. Tropical storm Edith began development on September 9th and marked the beginning of rather brisk activity throughout the remainder of September and the first two decades of October. Activity was mainly in the Gulf of Mexico and the western Atlantic and only one cyclone developed to hurricane intensity east of Longitude 50.

A total of seven tropical cyclones reached the coast of the United States. Of this number, three were of hurricane intensity, two barely reached hurricane force. Loss of life

TABLE 1

Storm	Principal area affected	Damage	Deaths U. S.	Deaths outside U. S.	Max. wind, mph	Lowest barometer
Arlene	Louisiana	$500,000	1	0	40–50	1000 mb 29.53 in.
Beulah	Mexico	Unknown	0	Unknown	Est. 70	Est. 987 29.15 in.
Unnamed	S. Florida Nova Scotia	$1,656,000* Unknown	0	33	Est. 90	974 mb 28.75 in.
Cindy	S. Carolina	$75,000	1	0	65 mph	997 mb 29.44 in.
Debra	Texas	$7,000,000	0	0	89–90 G-105	984.4 mb 29.07 in.
Edith	Windward Islands	Minor	0	0	35 mph	1007 mb 29.74 in.
Flora	Azores Islands	Unknown	0	Unknown	75 mph	994.2 mb 29.36 in.
Gracie	S. Car., Ga., Virginia	$14,000,000	22	0	97 mph G-138	950 mb 28.05 in.
Hannah	Azores Is.	Unknown	0	Unknown	Est. 125	959 mb 28.32 in.
Irene	Extreme NW Florida	Minor	0	0	60 mph	1001 mb 29.56 in.
Judith	S. Florida	Minor	0	0		

* Damage occurred in City of Miami in connection with a tornado during the formative stages.

in the United States was 24, of whom 22 resulted directly or indirectly from hurricane Gracie, one each as a result of tropical storm Arlene and hurricane Cindy. The total damage in the U. S. was approximately $23.25 million. The unnamed hurricane in mid-June caused the loss of 33 deaths and considerable damage in the Canadian Maritime Provinces, particularly in the Nova Scotia area. No other known deaths occurred outside the United States and damage was insignificant. Statistics on damage and fatalities are shown in Table 1.

Above and deeper than normal easterly winds were in evidence during the latter part of May and early June, when tropical storm Arlene formed in the central and western Gulf of Mexico. Height averages at 700 and 500 mb were above normal over much of the U. S. with a deficit in the Gulf of Mexico and eastward across Florida into the Atlantic. These conditions persisted during most of June and July, and tropical cyclone activity continued at an above normal rate.

During August the easterlies were weaker than normal over the hurricane belt and activity was practically nil. In September, above normal easterly flow set in again as 700 and 500 mb heights were below normal over the Atlantic to the north and northeast of the Antilles and above normal over the northeastern U. S. The cold trough that persisted over the middle Atlantic Ocean at middle and upper troposphere levels during August disappeared at lower latitudes. As a result, tropical cyclone activity was above normal during September and continued until mid-October when the westerlies migrated southward and brought an end to activity in the hurricane belt.

There follows a resume of the individual storms of the 1959 hurricane season:

1. Tropical Storm Arlene, 28 May–2 June

As early as 23 May an easterly wave was located in the vicinity of the Dominican Republic, which moved westward across Florida on the 27th and developed into tropical storm Arlene in the central Gulf of Mexico. It moved inland on the Louisiana coast between Weeks Island and Pt. Au Fer during the afternoon of the 30th. Highest winds reported in the storm were 40 to 50 mph on the Louisiana coast and the lowest pressure was 1001 mb. The storm produced heavy rains of 11 to better than 13 inches in southern Louisiana and heavy but lesser rainfall in much of eastern Louisiana to northern Georgia. One man was drowned at Galveston, Texas, and flooding caused some crop damage.

2. Tropical Storm Beulah, 15–18 June

Tropical storm Beulah was detected during the night of 15–16 June in the west Gulf of Mexico at Latitude 23N, Longitude 96W. It drifted towards the northwest on the 17th, then turned southward and moved inland over Mexico south of Tampico on the 18th.

Highest winds were estimated by reconnaissance aircraft at 70 mph with lowest pressure of 987 mb. This is consistent with Fletcher's Formula (1) for maximum wind based on minimum pressure. The storm weakened rapidly on turning southward on the 17th, and winds were only about 35 mph as it moved inland. There were no known fatalities.

3. The Nameless "It" Hurricane, 17–21 June

An unstable easterly wave moved northwestward into the central Gulf of Mexico at the same time that tropical storm Beulah was developing in the west Gulf of Mexico. A weak closed circulation formed in the east-central Gulf on the 17th and drifted towards the northeast. While this center was some 250 miles off the Florida west coast, a tornado formed in extreme south Florida and moved across the city of Miami about 2200 E on the 17th, and caused approximately $1,656,000 damage, many injuries but no deaths. Another tornado formed north of Palm Beach at about the same time, and crossed a sparsely settled area with little or no damage.

The circulation traversed central Florida during the night of the 17–18th attended by heavy rains with winds up to 50 mph in gusts. "It" deepened over the Atlantic when moving into a diffuse frontal system, and early on the 19th the *S.S. Atlantic Union* reported a barometer reading of 993 mb and west-southwest wind around 80 knots.

"It" moved into the Canadian Maritime Provinces near the Northumberland Straits, and press reports indicate 33 deaths, mostly lobster fishermen, and considerable property damage.

The circular cloud bands of Hurricane Gracie form the background for an unusual photograph of a Navy Jet Photo Plane F8U-1P. Plane from the Jacksonville Naval Air Station penetrated the eye on 28 September 1959 as Gracie approached the South Carolina coast. Official Photograph U. S. Navy.

4. Hurricane Cindy, 5–12 July

The circulation that produced hurricane Cindy was first noticed on 5 July off the Florida upper east coast. On the 6th, winds just east of the center increased to 30 to 40 mph as considerable convective activity formed to the north of the center, and contributed to the conversion of the low from cold to warm core. Anticyclogenesis increased the gradient north of the center and Cindy developed and intensified. The eye was located by reconnaissance aircraft on the afternoon of the 7th about 190 miles east of Charleston with highest winds 60 to 65 mph and lowest presure of 997 mb.

The small storm moved on a northwest course, attaining hurricane intensity a short distance offshore, and the center passed inland on the South Carolina coast about 2145E on the 8th between Charleston and Georgetown. Winds of 65 mph were measured at McClellansville, a short distance inland, and squalls were estimated just about hurricane force.

One person was killed near McClellansville, S. C., and property damage was minor al-

though several small tornadoes occurred in northeastern North Carolina and southeastern Virginia. Heavy rains accompanied the storm as it moved on a curved path and passed northeastward over the Carolinas and out over the Atlantic near Norfolk, Va. The center passed over Cape Cod, Mass., with gusts up to 50 to 60 mph, and the remnants of Cindy passed out over the Gulf of St. Lawrence.

5. Hurricane Debra, 22–27 July

The beginning of hurricane Debra can probably be traced back to July 15th, when considerable shower and thundershower activity began in the western Bahamas and over Florida, under the influence of a cold core vortex which developed in the high troposphere. At the 500-mb level the circulation drifted slowly towards the southwest through the western Bahamas over western Cuba and into the east Gulf of Mexico by the 20th. The activity spread into the Gulf as the upper circulation flattened into an inverted trough and continued westward.

The weak surface circulation detected as early as 1900E on the 20th developed into hurricane Debra over the northwest Gulf of Mexico. This circulation continued weak until the 23rd, when winds up to 25 to 35 mph accompanied showers and squalls in the northwest Gulf and along the Louisiana and upper Texas coasts.

A tipoff that some intense weather was in the making in the west Gulf of Mexico came from the *S.S. Atlantic Navigator* at Latitude 23.7N, Longitude 94.5W at 1900E on the 23rd. This report indicated southwest wind of 23 knots with rough seas from the southwest and that a vortex was developing. This was borne out by reports from that area and to the north towards the Texas coast on succeeding maps during the next 12 to 18 hours.

Radar reports from the Dow Chemical Plant in Freeport, Texas, at 0733C, when the set was turned on, indicated that Debra was likely already a fully developed hurricane. Debra increased further in intensity during the afternoon and evening of July 23–24 and passed inland on the Texas coast between Freeport and Galveston near midnight on the 24th. She continued slowly northward across extreme east Texas and rapidly lost intensity on the 25th and 26th, and finally lost identity in central Oklahoma on the 27th.

The lowest central pressure in hurricane Debra was 984.4 mb from the Coast Guard Cutter *Cahoone* late on July 24th. Dickinson, Texas, reported 986.5 mb, the lowest reading from a land station. Highest reported wind was 80 to 90 mph with gusts to 105 mph from Brazos Floodgates near Freeport, Texas. Tides were generally 3 to 5 feet over Galveston Bay. Rainfall was heavy throughout east Texas and extreme western Louisiana. Orange, Texas, reported the greatest amount, 14.42 inches.

No casualties occurred in connection with Debra, but ten persons suffered minor injuries in Brazoria County. Damage in Brazoria-Galveston and eastern portion of Harris County was estimated at $6,685,000 and some additional in other areas.

6. Tropical Storm Edith, 17–19 August

Short-lived Edith formed in an easterly wave in the Atlantic Ocean east of the Windward Islands. A weak center was located by reconnaissance aircraft at Latitude 13.8N, Longitude 57.2W at 1630E of the 17th. Surface winds of 30 knots in squalls were found, and the lowest pressure was 1007 mb. At no time was the storm well defined. It moved on a west-northwest course around 20 knots and passed through the Leeward Islands in the vicinity of Guadeloupe early on the 18th. Highest winds were estimated at 48 knots and the storm lost its intensity a short distance south of Mona Passage during the night of the 18–19th. There is some doubt as to whether a complete circulation ever existed, and it appears that it likely remained in a strong easterly wave stage then weakened after passing into the eastern Caribbean.

Two important features were associated with this storm. Unusually warm air was observed in the middle troposphere just prior to the formation. The wind field in the high troposphere never became favorable for high level evacuation.

There were no reports of loss of life or of damage attributable to Edith.

7. Hurricane Flora, 9–13 September

The easterly wave in which Flora was spawned very likely passed through the Cape Verde Islands on 6 September. On the 10th,

Flora was located near Latitude 22.1N, Longitude 46.3W when ship and aircraft reports indicated highest winds of 45 mph and minimum central pressure of 1008 mb. The storm moved on a north course then towards the northeast and east-northeast and into the southernmost of the Arozes Islands late on September 12th, then combined with a large polar low later on the same date.

Reconnaissance aircraft indicated that Flora barely reached hurricane intensity on the 11th, with winds of 65 knots and a minimum pressure of 994 mb. On succeeding flights into the storm, hurricane force winds were not encountered.

Flora recurved rapidly to the north and northeast before she became a threat to any land areas, except the Arozes Islands, due to a major trough in the westerlies extending southward into the tropics. No loss of life or property damage has been attributed to Flora.

8. Hurricane Gracie, 20 September–2 October

Gracie was a major hurricane and one of the most troublesome and cantankerous of the 1959 season to forecast. The easterly wave in which Gracie formed had been followed some five days and its sudden development and intensification is difficult to explain. Her erratic movement between the 22nd and the 27th, which included most all directions of the compass, was impossible to forecast more than a few hours in advance (see fig. 1). The upper winds at all levels were rather light and variable over this section of the Atlantic during the period. On the 27th and 28th, the hurricane moved between west and west-northwest, then turned towards the northwest and passed inland on the South Carolina coast near Beaufort around noon on the 29th.

The easterly wave in which Gracie was spawned was noted in the Atlantic about midway between the Lesser Antilles and the West African coast on the 16th. During the next 5 days the wave moved westward around 20 mph and into the southeastern Bahamas where Gracie formed. Beginning on the 18th, the wave was investigated daily by reconnaissance aircraft. The portion of the easterly wave in the Atlantic north of the Antilles came to a halt on the 22nd as Gracie developed. The southern portion over the Caribbean sheared off and continued westward. The wave had been attended by heavy shower activity from its beginning, particularly over the ocean areas to the east and north of the Antilles. The island of Mayaguana in the southeast Bahamas reported 8.40 inches of rainfall during the 12-hour period from 1900 of the 21st until 0700 of the 22nd. The hurricane was quite wet during its entire history.

The surface pressure pattern over the Atlantic during the period September 16–29 was about normal. Probably the most important feature was the movement of a strong polar anticyclone from the northern U. S. into the western Atlantic resulting in strong anticyclogenesis and an increase in the low level easterlies in the southwest Atlantic. The initially cold high was gradually transformed into a warm anticyclone which extended well into the middle troposphere. The passage of weak short waves in the polar westerlies to the north of the hurricane weakened the high and resulted in a very weak steering current. Rising heights at upper levels on the 27th north and northwest of Bermuda increased the easterly current, with the result that Gracie finally was steered on a definite course.

During the period from the 22nd to the 24th, the circulation in the upper troposphere was very complex and contained many small-scale cyclonic and anticyclonic eddies. On the 28th and 29th the anticyclonic flow had simplified greatly and the center again became located north and northeast of Gracie which resulted in a rather uniform steering current from the east-southeast throughout the entire troposphere.

Gracie was rather erratic in intensity as well as movement. On the 22nd the cyclone deepened rapidly to 997 mb with winds of 90 to 100 mph. On the 23rd the central pressure varied from 1000 to 1006 mb with winds 45 to 65 knots. On the 25th the minimum barometer again dropped to 997 mb and reconnaissance aircraft reported an increase in maximum winds, the size of the storm area and the intensity of weather around the eye. On the 27th the central pressure decreased further to 979 mb with an almost complete wall cloud. The hurricane continued to intensify further during the next two days to 950 mb.

As Gracie made landfall, a minimum pres-

The cloud structure in the eye of Hurricane Gracie with surrounding cloud wall as photographed on 28 September 1959 by Commander Hill of the Fleet Air Photographic Laboratory, Naval Air Station, Jacksonville. Official Photograph U. S. Navy.

sure of 950 mb was reported by the Marine Corps Auxiliary Air Station at Beaufort, S. C., and a sutained wind of 97 mph with gusts to 138 mph. The wind was estimated as high as 175 mph closer to the exact center of the storm. It is likely that gusts to at least 150 mph occurred.

Rainfall of 3 to 8 inches occurred in South Carolina and portions of Georgia, while in North Carolina 2 to 4 inches were reported with local amounts up to 8 to 10 inches. Some flooding occurred, particularly in the Carolinas and Virginia, and crop damage, due to wind and rain, was heavy in South Carolina and eastern Georgia. Rainfall was beneficial in most sections from North Carolina northward, helping to break the near drought conditions in many areas.

Ten persons lost their lives in South Caroline and Georgia, mostly due to automobile accidents, falling trees, and live wires. Several tornadoes attended the passage of the dying storm through Virginia and twelve persons were killed in one of these tornadoes at Ivy near Charlottesville. Wind damage was severe near the eye in the coastal area as Gracie moved inland and the greatest in the history of Beaufort, S. C. Damage has been

estimated at $14 million, about half of which occurred in Charleston County, S. C.

Accurate forecasting of the erratic movement of Gracie during its early stages was beyond the present development of the science of meteorology. After the steering current became simplified on the 27th, the forecasts and warnings issued were exceptionally accurate. The Carolina coasts were placed on an informal hurricane watch as early as 0500E on the 27th, and hurricane warnings were issued at 1400E on the 28th for the area from Savannah to Wilmington. As a result of the timely warnings, exacuation from vulnerable islands and beaches was almost total. Effective community action on the basis of these warnings and the landfall of Gracie near the time of normal low tide was responsible for the low loss of life. There were no known fatalities from hurricane tides and waves. Maximum tides of 8 to 11 feet above normal were forecast and the maximum measured tide was 9 to 12 feet MSL.

9. Hurricane Hannah, 27 September–8 October

A cyclonic circulation was located in the Atlantic by surface ship reports on September 27th near Latitude 27N, Longitude 50W. Aircraft reconnaissance the following day indicated a fully developed hurricane at Latitude 27N, Longitude 57W, with maximum surface winds of 85 mph and moving towards the west at 16 mph.

The hurricane increased in intensity during the following 48 hours with central pressure dropping to 959 mb and maximum winds of 125 mph. The intensity remained about the same during the next three days as the storm curved northward about 200 miles west of Bermuda and then accelerated in forward movement towards the east on October 4th. The last advisory was issued when the hurricane was 200 miles south-southwest of the Azores on the 6th. Winds near the center at this time were still estimated 100 mph. Details of later stages are lacking but indications are that a gradual decrease in intensity then began as the storm moved northeastward merging with an intense cyclone centered southeast of Greenland.

10. Tropical Storm Irene, 6–8 October

Tropical storm Irene formed in the central Gulf of Mexico on October 6th, moved north-northeast during the next two days and passed inland near Pensacola during the morning of the 8th.

Irene was never a well organized storm and although the center moved inland near Pensacola, the highest tides were 4.4 feet above normal at Cedar Keys, Fla., a considerable distance east of the track. The lowest sea level pressure reported by reconnaissance aircraft was 1001 mb. The highest wind was 55 mph in gusts in squalls at the Pensacola Airport. No deaths were reported and damage was insignificant.

11. Hurricane Judith, 17–21 October

Moderate activity occurred in the Caribbean and Central America during mid-October with the result that a weak circulation was located south of Jamaica on the 15th. This weak circulation was investigated daily by reconnaissance aircraft as it drifted into the northwest Caribbean, through the Yucatan Channel, and into the extreme southeast Gulf of Mexico. Up to this time, winds of 50 to 55 mph had been reported in squalls, with a minimum central pressure of 999.3 mb.

The storm turned northeastward and the center reached the Florida west coast near Boca Grande Island on the morning of October 18th. It crossed south Florida during the day, causing heavy rains with winds up to 55 mph in gusts over the southern third of the peninsula. As the storm moved out into the Atlantic near Ft. Pierce, Fla., a new center apparently developed just northeast of Great Abaco Island in the Bahamas and rapidly intensified to hurricane force by the morning of the 19th. The storm moved towards the east-northeast, passed a short distance south of Bermuda during late afternoon of the same date. At this time the storm was becoming involved with a cold frontal system and by the 21st had lost hurricane force. Thereafter, the storm became extratropical and decreased further in intensity.

There were no deaths in connection with Judith and damage was minor.

REFERENCE

1. R. D. Fletcher, "Computation of Maximum Surface Winds in Hurricanes." *Bulletin of AMS*, Vol. 36, June 1955, pp. 247–250.

Intriguing snow rollers dot a wintry hill slope at Lanesboro, Massachusetts, on 8 December 1959, as wind sweeps over a wet snow surface. Photo by William H. Teague. Courtesy of Nesbitt H. Bangs, cooperative USWB observer of Stockbridge, and the *Berkshire Eagle* of Pittsfield.

Some Noteworthy Snows of 1958-59

DAVID M. LUDLUM

NEW ENGLAND SNOW SEASON

SNOW lovers in New England were much disappointed with the behavior of the white flakes during the winter of 1958–59. There was only one good old-fashioned snowstorm, and the season's totals fell well below normal. March, as in the past several years, brought the most snow and the one substantial storm. Seasonal totals at industrial cities along the coast were: New Haven 18″, Providence 25″, Boston 34″, and Portland 60″. At inland points the highest totals in each state were far below the peaks of the previous snowy year: Connecticut (Norfolk 96″), Rhode Island (Woonsocket 35″), Massachusetts (Hoosac Tunnel 99″), Vermont (Newport 111″), New Hampshire, excluding mountain-top stations (Pinkham Notch 165″), and Maine (Caribou 113″).

The major storm occurred on the 71st Anniversary of the Great Blizzard of 1888, the granddaddy of all northeast snowstorms. A small low developed over the lower Mississippi Valley and moved to a position in West Vir-

ginia (1000 mb—29.53″) at 0100 on the 12th. Cold Arctic air overlay Quebec Province, but there was no large blocking anticyclone as usually exists during New England's deep snows. Snow broke out all over New England soon after midnight of the 11–12th. The center moved to the coast at Cape May, New Jersey, by 1300, and then turned north-northeastward, to cross outer Cape Cod and reach the Gulf of Maine by 0100 of the 13th. Central pressure plummeted to 972 mb—28.70″. Whole gale winds with gusts to 70 mph swept the coastline. Snow covered all New England with 4″ to 8″ in the south and 15″ to 20″ generally in the north. Old Town, Maine, reported the greatest new fall with 24″. Blizzard conditions existed over all northern New England on the 13th as gale winds out of the northwest kept the snow flying. Schools were closed, air traffic suspended, and surface movement seriously hampered as the gales frustrated efforts to open lines of communication.

The mid-March falls brought the snow cover to the highest levels of the season. Pinkham Notch had 68″ on the 13th, but thereafter the cover decreased rapidly. The top amounts in other northern locations were: northern Vermont (Newport 40″), northern New Hampshire (First Connecticut Lake 39″), and central Maine (Greenville 55″). By the 1st of April snow had disappeared in all but northern locations—by the 13th of April it was gone in the northern Vermont valleys, by the 14–16th in northern New Hampshire, and by the 18th in northern Maine.

Hard Winter in New York State

Folks in upper New York State experienced a snow season of the old-fashioned variety. The first general storm occurred on 28–29 November as a low moved up the Ohio Valley and covered most of the northern sections with 6″ and more. From 5 to 11 December repeated snow squalls along the lee shores of Lake Ontario and Lake Erie dropped up to 72″ of new snow to create many local records. In January two near-blizzard periods occurred: on the 3–7th continued westerly gales with squalls and blowing snow swept the area in the rear of a stalled low presure center off New England; then on the 15–18th gales and heavy snow hit again. Bennett's Bridge in the hills just east of Lake Ontario had a snowburst of 51″ in 16 hours.

February brought seven distinct winter storms. On the 1st and 6th snowbursts again visited the lee shores of the Lakes. On the 3–4th, 10–11th, and 13–14th glaze conditions spread over many parts of the State. More heavy snow showers at the end of Lake Ontario on the 21st were followed on the 23rd by a general snowstorm which dumped up to 10″ over much of New York.

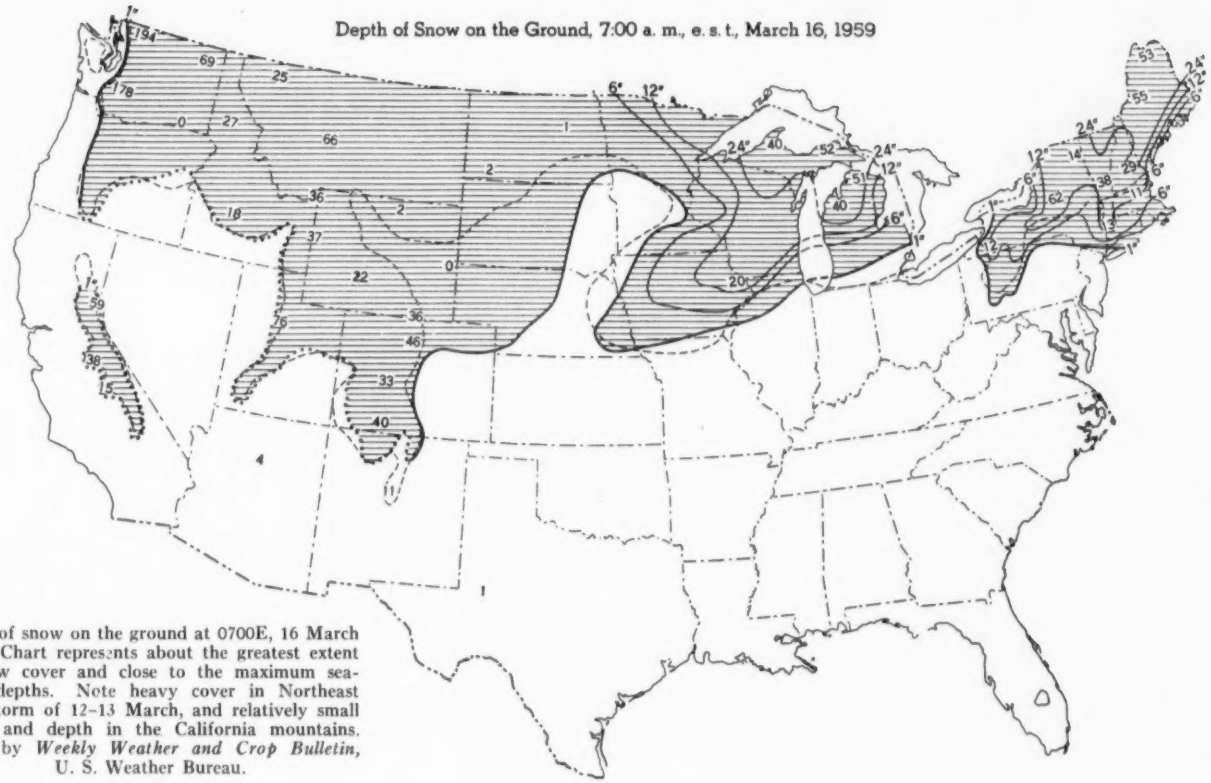
On 6–7 March heavy rains accompanied by gales changed to snow as winds got around to northwest and increased in some places to hurricane force. The major storm of the winter, as in New England, occurred on the anniversary of the Great Blizzard when from 12″ to 20″ fell in central and eastern portions of the State to paralyze traffic and communications. On the 16–17th more snowbursts along Lake Ontario dropped up to 12″, to be followed by still more on the 27–28th. There were no April falls on note as spring came on fast.

It was a record year for total snowfall. Large cities in the central part of the State received the following: Rochester 140.6″, Syracuse 137.2″, Oswego 169.5″, and Rome 133″. In three of the past four years snowfall at Syracuse, whose record dates back to 1902, has either exceeded or closely approached all-time records.

In the northern interior in the heart of the Adirondack Mountains many stations reported over 150″ (Stillwater 211.7″). Maximum snow cover was generally reached after the storm of 12–13 March when Newcomb and North Creek each had 51″. In the snow belt east of Lake Ontario Boonville had a seasonal fall of 288.5″ and Bennett's Bridge 261.5″. The maximum depth at Boonville was 62″ on the 12th.

December Snowbursts Along the Lakes

The snowburst mechanism along the lee shores of the Great Lakes functioned in fine style during December 1958. Both in Upper and Lower Michigan and along the lee shores of Lake Erie and Lake Ontario tremendous snowfalls made national headlines. December 1958 ranked with the coldest Decembers on record in northern sections. As the successive cold air masses passed over the relatively



Depth of snow on the ground at 0700E, 16 March 1959. Chart represents about the greatest extent of snow cover and close to the maximum seasonal depths. Note heavy cover in Northeast after storm of 12–13 March, and relatively small extent and depth in the California mountains. Chart by *Weekly Weather and Crop Bulletin*, U. S. Weather Bureau.

warm waters of the Lakes, spectacular snowstorms resulted.

At the CAA Airport near Houghton, Michigan, on the Keweenaw peninsula jutting out into Lake Superior, December brought a total snowfall of 107.6″. It snowed a measurable amount on every day but five in the month. The two greatest falls came early—13.3″ on the 8th and 11.7″ on the 9th—to raise the total on the ground to 49″. Additional snows again fell from the 20th to the 24th to maintain a snow depth of 48″ for Christmas Day. The final seasonal figure reached a total of 242″ at Houghton.

It was a good snow season elsewhere in Michigan. Munising, a lee shore location on Lake Superior, had a total of 201.9″, of which 84″ fell in December. At Sault Ste. Marie the snow depth increased to 40″ by March 16th, the greatest depth ever measured there since the weather station opened in 1888. Further south in central Michigan, Muskegon on the eastern shore of Lake Michigan compiled an impressive total of 131″, the greatest in its history, as both lee shore showers and cyclonic storms to the south combined to boost its total.

The lee shores of Lake Ontario in the vicinity of Oswego, New York, had the most newsworthy falls. At Oswego State Teachers College the December total reached 85.8″—nothing like this had occurred since 1856. In the immediate vicinity unofficial totals reached 100″. The big day came on the 8th when 40″ fell in one grand burst. Snow depths the next day amounted to 47″. Further inland near the peak of the first substantial ridge to the east, Boonville, where snow-watching Livingston Lansing resides, December had a total of 82.8″ and the maximum snow cover reached 45″. It was the same story at the end of Lake Erie where Mayville in extreme southwestern New York State had about the same totals as Oswego. And again, Erie, Pennsylvania, had 45″ in December and a maximum cover of 25″ to hamper traffic in that often-snow-clogged industrial city. In the hills of northeastern Ohio facing Lake Erie, Geneva had 48″ in December with a maximum cover of 25″ after a six-day storm ending on the 10th had deposited a total of 36.5″.

Deep Carolina Snow

A major Carolina snowstorm developed along the southern fringe of a cold air mass overlying the North Atlantic States on 11–12 December 1958 when a wave formed on a frontal zone overlying Florida early on the 11th and developed northeastward with rapidly increasing energy. At 0100 on the 11th a rain area extended northward into Georgia and South Carolina, and this soon changed to snow in central South Carolina as cold air was drawn southward by the increasing cyclonic circulation around the low. By dawn of the 11th heavy snow had spread into North Carolina as the main low pressure area moved northeastward to a position off Cape Lookout by 1300. The heavy snow area extended from Columbia, South Carolina, northeastward in a belt about 50 miles in width, across east-central North Carolina to the Norfolk area of Virginia.

Columbia in central South Carolina had 8.8″ (the heaviest in 44 years) and Cheraw to the northeast measured 12″. In North Carolina amounts on the 11th ranged up to 15″ at Pinehurst and 16″ at Rocky Mount. Elizabeth City on Albemarle Sound close to the ocean gathered 12.8″. The Norfolk area of the lower Chesapeake Bay region also received heavy falls with 11.4″ at Norfolk Airport, 14.5″ at Mathews, and 15″ at Langley Air Force Base.

In central South Carolina this was the heaviest snow since 11.7″ fell in February 1914, Columbia's all-time high since measurements commenced in 1887. In central and eastern North Carolina it was the greatest snowstorm since March 1927 when 31″ fell at Nashville (40 m. northeast of Raleigh). In southeastern Virginia it was the heaviest 24-hour fall since 17.7″ fell at Norfolk in December 1892.

Snowbound Wisconsin

The upper Mississippi Valley experienced the coldest winter generally since the record-breaker of 1935–36. Although the cold was widespread over the vast area, the deep snow falls were concentrated in a relatively small band in the four-state area where Wisconsin, Iowa, Illinois, and Minnesota are in close proximity.

(*Continued on page 39*)

The Weather Past—March

1	1914	Heavy wet snow "worst since '88" crippled New York-New Jersey—*Congressional Limited* lost—24″ Asbury Park—NYC's lowest bar. 28.38″.
2	1846	Great NE storm and tide in Virginia—5′ above normal at Norfolk—$500,000 damage—50 families, 1000 cattle drowned at Nott's Island, N. C.
3	1947	Vermont's deepest modern snowstorm—Readsboro 50″ in 3 days. Massachusetts' deepest modern snowstorm—Peru 47″ in 3 days.
4	1717	Colonial New England's "Great Snow" ended—about 36″ in 3 storms—no traveling, rural church services for 3 weeks—sheep buried 30 days.
	1909	President Taft inaugurated in furious NE snowstorm at Washington.
5	1872	Severest modern March cold wave—NYC 3°, lowest ever in March.
6	1723	Famous high tide in Massachusetts—unequaled until 1851.
7	1932	Wash., D. C.—severe storm, rain-sleet-snow-gales—28.67″ record low.
8	1941	Heavy snowstorm swept Northeast—12″+ Maryland to Maine.
9	1911	Tamarack, Calif.—454″ snow on ground—U. S. record.
10		
11	1888	Great Blizzard of '88 commenced as rain in New York and New England.
12	1888	Albany, N. Y.—30″ new snow in 24 hours.
13	1888	Total 3-day snowfalls: 58″ Saratoga, N. Y., 50″ Middletown, Conn., Albany 46.7″, New Haven 44.7″, New York City 20.9″, Boston 10″.
14	1870	Severe 3-day blizzard struck Minnesota and Iowa—great losses.
15	1941	Severest recent blizzard: Grank Forks, N. D. 85 mph, Duluth 68 mph.
16	1843	Great NE snowstorm swept from Gulf to Maine—Natchez, Miss. 4″, Shelbyville, Tenn. 21″, Phila & NYC 12″, Brunswick, Me. 8″.
17	1892	Heavy snow in Tenn.—Riddleton 26″ in 3 days, Memphis 18″.
	1906	−50° Snake River, Wyo., lowest ever for March in U. S.
	1956	St. Patrick's Day deep snow at Boston—Blue Hill 12″ with gales.
18	1925	Great Tri-State Tornado in Ill., Ind., Ky.—greatest U. S. tornado disaster—737 deaths: 234 Murphysboro, Ill.; 127 W. Frankfort, Ill.
19	1956	Boston's 2nd heavy snow in 3 days—traffic paralyzed—Blue Hill 19″.
20	1958	Southeastern Penna. and Maryland—40″ wet snow—area snowbound.
21	1801	Jefferson Flood in Connecticut Valley, greatest since 1692—so named by Federalists who blamed disaster on new president.
	1932	Alabama—Chilton County tornado killed 53 persons.
	1952	Arkansas—tornado outbreak over state killed 111.
22	1936	Great floods at height on Ohio, Penna., N. Y., and New England rivers.
23	1913	Omaha, Nebraska, tornado killed 95.
24	1912	Kansas City's greatest snowstorm—25″ in 24 hours.
25	1843	Second great NE snowstorm from Gulf to Maine—Natchez, Miss. 3″—east Tennessee 15″—Concord, N. H. 8″.
26	1913	Great floods on Miami River in Ohio—732 deaths.
27	1951	South Dakota's deepest snowstorm—Dumont 38″ 24 hours—60″ 3 days.
28	1945	Record March heat wave: 90° Providence, 91° in N. Y., N. J., Pa., Md.
29	1921	Wash., D. C.—great temp. drop ended record early spring—82° to 26°.
30	1823	NE snowstorm with hurricane winds—Penna. to Maine—uprooted trees.
31	1954	108° Rio Grande City, Texas—highest ever for March in U. S.

The Weather Past—April

1	1807	Famous 1807 storm in New England—great tide on coast, deep snow interior—Danville, Vt. 30″ new snow, cover 60″—great freshet followed.
2	1837	Great April snow, St. Louis and vicinity—17″ city, 2′ outside.
3	1915	Heavy Easter snowstorm in Penna. and N. J.—19.4″ at Phila.
4	1804	Severe tornado crossed 6 Georgia counties—11 killed near Augusta.
5	1945	−36° at Eagle Nest, New Mexico—lowest ever in April for U. S.
	1926	Opid's Camp, Calif.—0.65″ rain in one minute.
	1936	Tupelo, Miss., tornado—216 deaths.
6	1936	Gainesville, Ga., tornado—203 deaths.
	1828	Florida freeze: 30° St. Johns River—followed mildest winter of record.
7	1857	Severe Southern freeze—Houston, Texas, 21° and ice.
8	1929	Record heat wave in East—earliest 85° at NYC on both 7–8th.
9	1947	Tornado killed 95 at Woodward, Okla., 51 at Higgins, Texas.
10		
11	1841	Big April snow—New York 12″, New Jersey 24″—"Tippecanoe & Tyler too" victory parade impeded—marshal developed pneumonia and died.
12	1861	Bombardment of Ft. Sumter—Rain all day (0.55″)—temp. 72° at 1400.
	1927	Tornado wiped out Rock Spring, Texas—72 deaths.
	1934	Mt. Washington, N. H.—wind gust at 225 mph from SE—U. S. record.
13	1857	Big late snow in South—4″ accumulated in Alabama.
14	1873	Famous Easter Blizzard in Kansas, Nebraska, South Dakota—whole gale blew wet snow into huge drifts—many new settlers perished.
15	1854	Great Pacques Storm in New Jersey—24″ accumulated at N. Brunswick.
	1921	Most intense U. S. snowfall—Silver Lake, Colo.—76″ in 24 hours.
16	1851	Famous Lighthouse Storm—great tide and whole gales destroyed Minot Light with keepers in Boston Harbor—tide level approached in Dec. 1959.
	1849	Severe freeze Georgia to Texas killed cotton—snow at Charleston.
17	1821	Boston, Mass.—est. 24″ snow prevented opening of Legislature.
18	1906	San Francisco Earthquake, rare east wind drove fire across city.
19	1775	Crisp, post-cold front weather greeted British at Lexington Common—John Winthrop at Cambridge: 0600—57.5°, West force 1, very fair—"Battle of Concord will put a stop to observations."
	1881	Nation City, S. D.—79-day snow blockade on railroad lifted.
20	1851	Late season snowstorm: New Haven 5″, Newark 4″.
21		
22	1958	Montana snowburst: 55″ Red Lodge, 61″ Nye Mine, 72″ Mystic Lake.
23	1885	Denver's greatest snowstorm: 23″ in 24 hrs—Idaho Springs, Colo., 32″.
	1910	Los Angeles' earliest 100° temperature.
24	1908	Tornado—Lamar-Wayne Counties, Miss.—100 deaths.
25	1898	118° at Volcano Springs, Calif.—highest ever for April in U. S.
26	1834	Huntsville, Ala.—severe frost highlighted very backward spring.
27	1915	Washington, D. C. 95°—highest ever in April.
28	1928	Heavy snow: Bayard, W. Va. 35″, Grantsville, Md. 30″, Carlise, Pa. 26″.
29	1905	2″ rain in 10 minutes at Tyler, Texas.
30	1852	New Harmony, Ind. tornado—track Ill. to Ky. parallel to March 1925 Tri-State Tornado—killed only 16 due to sparse settlement.

Weatherwatch

Data by Office of Climatology, USWB.

Record Cold November: Lack of Cold in December

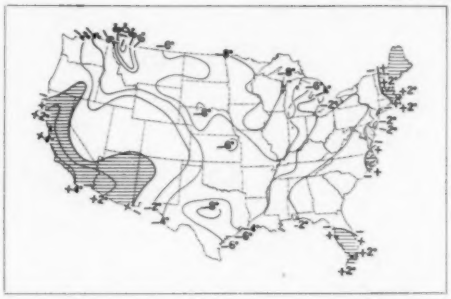
DAVID M. LUDLUM, *Editor*

CIRCULATION—An excess in mass of air over the northern latitudes of North America set the stage for the distinctive types of weather events which most of the country experienced in November. The pressure build-up in the North shows up very clearly on the mean surface weather charts for the month—much above normal over British Columbia 9 mb (.27″), while in Florida the mean barometer averaged about 2 mb (.06″) below normal. This great pressure gradient from northwest to southeast permitted great surges of Arctic air to flow southeastward to make November 1959 one of the coldest ever experienced from the Rockies to the Appalachians, and from Canada to the Gulf of Mexico. The Arctic air masses after entering the United States possessed unprecedented coldness: many new low records were set from Montana to Florida for early season cold, for absolute November minima, and low monthly average.

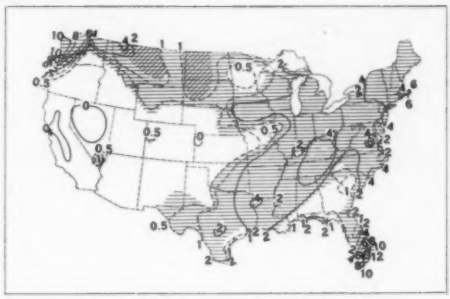
A reading of −53° registered on the 16th near Lincoln, Montana, at an elevation of 5,150 ft., was the lowest ever recorded officially in the United States during any November.

The upper-air circulation charts, of course, reflect the surface departures from normal. Across the United States in November a western ridge-central trough-eastern ridge pressure pattern prevailed on all but four or five days, representing a continuation of the same formula which had brought early wintry conditions to the Plains in mid-October.

The western ridge in November maintained a position from the Canadian Yukon southward across British Columbia and then along 125° W just off the California coast. When at its maximum development in the middle of the month, the feature presented a most imposing physical structure. It provided an inpenetrable block for Pacific fronts and air masses seeking to enter the continent from the west, and at the same time the air flow on its eastern flank accelerated the movement of frigid air from the deep Arctic into the Canadian Northwest. The ridge provided the birthplace for two great anticyclones of the 1050 mb-31.00″ class from the 10th to the 14th, both of which set new all-time records for early season cold and snow when entering the United States. The western ridge also provided much of California with an almost rainless November to compound the water shortages brought on by an almost rainless October. As a further contribution, anticyclonic subsidence plus easterly circulation



Departure of Average Temperature from normal in degrees Fahrenheit. USWB chart.



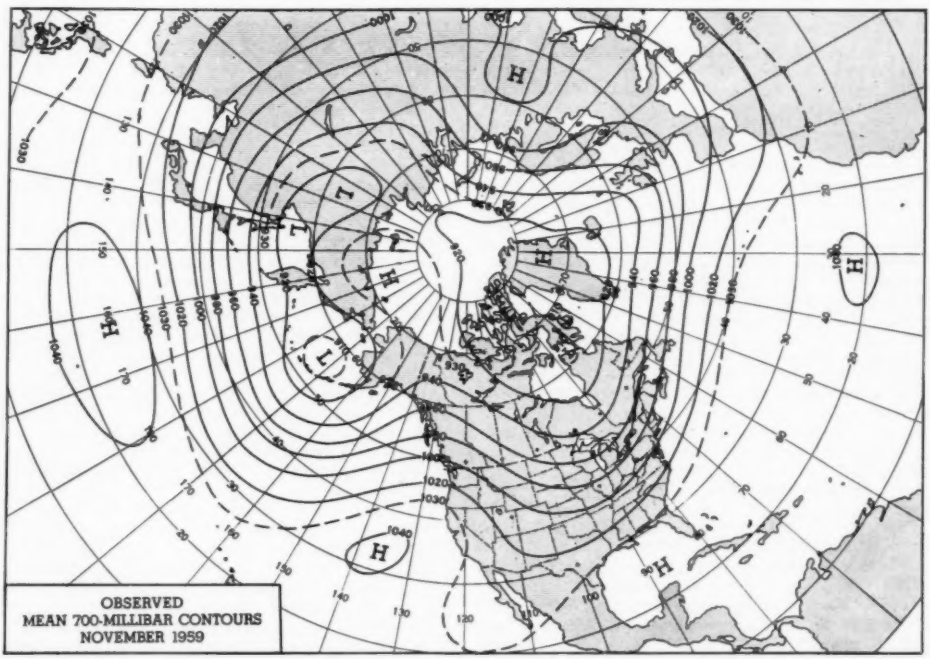
Total Precipitation in inches USWB chart.

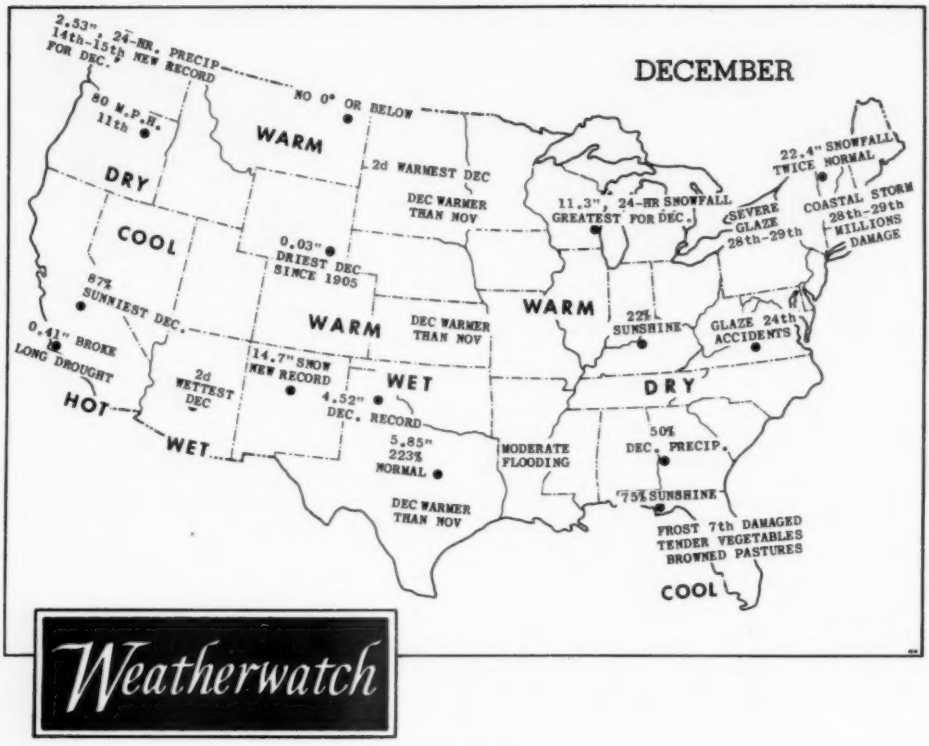
warmed the California littoral to continue the long series of abnormally warm months there.

The central trough extended from the Hudson Bay area south-southwestward over Wisconsin, and then took a pronounced southwesterly turn as it crossed Missouri and Oklahoma. Though the surface pressure departures from normal in the trough were quite small, the magnitudes of the ridges lying to the west and to the east created a vigorous flow into and out of the central trough feature. Practically all cyclonic activity on continental North America was associated with the central trough, and chiefly in its northern sections. U. S. storms moved mainly northeastward from the Great Lakes to Quebec. Several cyclones, stalled by the blocking ridge over Greenland, developed very intense circulation as central pressures deepened—960 mb (28.35″) on the 26th over Labrador, and 961 mb (28.38″) on the 3rd in Davis Strait. It should be pointed out that practically all the severe storms of the month occurred in Canada; in the U. S. only the Northwest

(*Continued on page 37*)

The upper-air map below shows the pattern of air flow for November at about 10,000 feet, on which the average weather largely depends. The contours lines represent the mean height of the 700 mb. pressure level. Figures are in tens of feet: 1020 = 10,200 ft., 980 = 9,800 ft., etc. Chart by Extended Forecast Section, USWB.





Weatherwatch

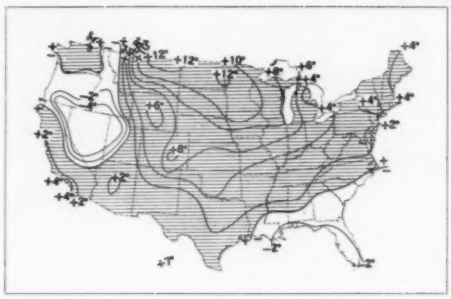
CIRCULATION—December proved a warmer month than November at many stations in the upper and central Mississippi Valley and on the Plains. This unusual, but not unprecedented, fact provided the highlights of the weather in the month under consideration. In central Minnesota at St. Cloud with records dating back to 1881, it was only the third time that a December averaged warmer than the preceding November, but this December's excess of 3.8 degrees far exceeded the differential of the previous two such contrasts which, by the way, occurred way back in 1894 and 1896. Minneapolis experienced the second warmest December since 1871, averaging 4.7 degrees warmer than the previous November and 14.2 degrees warmer than December 1958. Bismarck, too, had some records for the books. It was the second warmest December of record (exceeded only by 1939), every day of the month averaged above normal, and for the first time since 1877 no zero or lower readings were registered in a December. In Montana, where a −53° reading had been registered on 16 November 1959, no general cold wave with below zero readings occurred. Surely, these considerations make November 1959 a standout more abnormal than first suspected.

The reasons behind this remarkable reversal of temperature form are not difficult to find. In a word, mild Pacific air constantly occupied the arena where frigid Arctic air had dominated 30 days before. In November the great ridge over the Pacific States had served two purposes: (1) to block the inflow of air masses from the Pacific, and (2) to facilitate the descent of Arctic air into the United States.

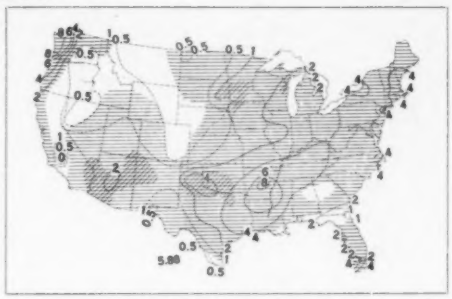
Outstanding on the December mean upper-air flow charts was a deep low center over southern Alaska. This represented an eastward displacement and further development of the low feature found over the central Aleutian Islands chain the previous month. Surface pressure averaged 11mb/.33″ below normal along the Alaskan-Yukon border in December, a shift of minus 17mb/.51″ from the previous month. Constant cyclonic activity in the Gulf of Alaska, in concert with a tight pressure gradient to the southward, provided a strong southwesterly air flow into the Alaskan Panhandle, British Columbia, and the interior of the Canadian Northwest; this steering current pushed many pressure impulses over the coastal mountains resulting in active cyclogenesis in Northwest Canada. The Arctic front, which had freely penetrated deep into the United States before, now remained confined to the region north of the Arctic Circle, so that mild maritime air from the Pacific Ocean occupied the Prairie Provinces of Canada and the northern border states of the U. S. without challenge.

With pressure much below normal over the polar regions, the United States had almost uniformly near-normal pressures. The greatest departure at the surface lay over the Northwest where Washington-Oregon averaged plus 3mb/.10″ to reflect the strength and persistence of the Plateau high situation.

The central trough of November, the scene of so much weather activity, moved eastward with a shift



Departure of Average Temperature from normal in degrees Fahrenheit. USWB chart.

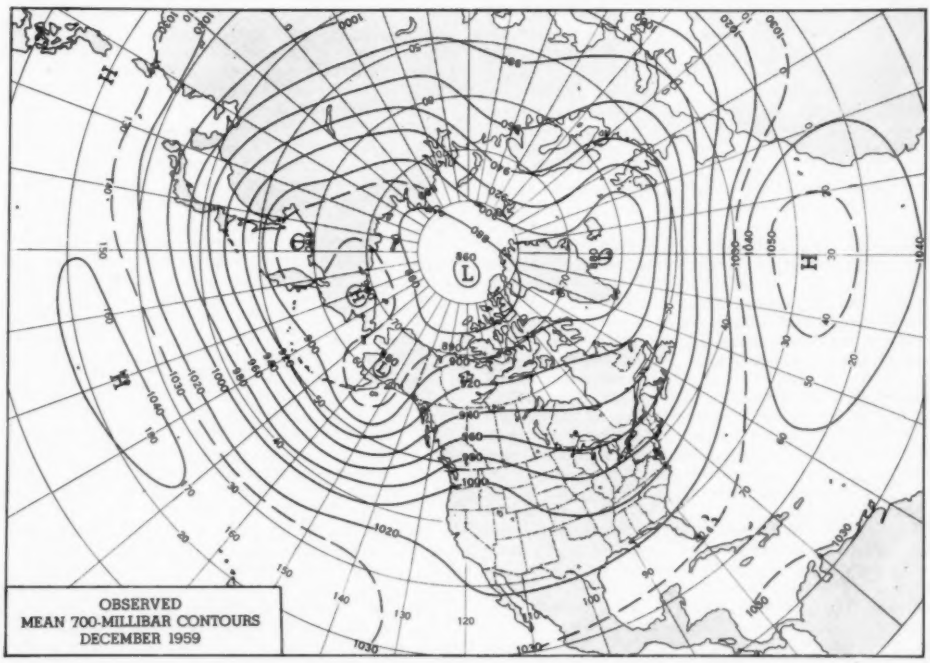


Total Precipitation in inches USWB chart.

of the planetary waves, flattened out considerably, and occupied a mean trough position from Maine southwestward to central Texas. Most significant for subsequent weather events in the U. S. was the disappearance of the sub-polar vortex over the Canadian Arctic archipelago and the Hudson Bay region. Eastern Canada now had almost west-to-east flow contours, so that Arctic air here could not penetrate southward until the last few days of the month. The blocking high over Greenland also disappeared, and an Icelandic low complex occupied its normal region after a two-month absence. A high index of westerly circulation prevailed over all the middle latitudes of the Western Hemisphere. The weather across the continent reflected this type of pattern with an absence of news-making events.

Anticyclones played a more prominent role in December than did cyclones. For all but one week a Plateau high could be found over the Western States. This type anticyclone usually is composed of modified Pacific air and produces mild days and relatively cold nights with very little precipitation. The only definite break in this regime commenced on the 20th; for the following week three Pacific lows approached the California coast and finally broke the long-continued fall and early winter drought. Once again on the 27th the Plateau high reestablished supremacy over the interior of the West, and the weather regime reverted to its former orderly state.

Another anticyclonic type appeared over central Canada on the 18th with the build-up of a Hudson Bay high, a feature which was destined to dominate the weather from the Rockies to the Atlantic Coast until the year's end. The persistence in strength and



slow movement of this high were unusual; it took from the 19th until the 25th to move from a position north of Winnipeg to the longitude of Quebec City (a distance of 1250 miles), all the while maintaining a pressure in the vicinity of 1040–44mb/30.70–30.83″. On Christmas Day the ridge line of the high finally passed eastward off the Middle Atlantic States coastline, but immediately another high of the same general character reappeared over northwestern Hudson Bay on the 26th and drifted slowly southeastward to southeastern Hudson Bay by the 29th. Although not of the magnitude of its predecessor, it was situated farther west and provided the Northern States with a real winter storm to mark the exit of 1959.

RAIN COMES TO CALIFORNIA—The Golden West received the best possible Christmas present in the form of a soaking rain which was still falling in the South as Santa Claus was distributing his wares. The aforementioned Plateau high, which held strong all fall and early winter, commenced to weaken on the 20th when a very deep low of 976mb/28.82″ developed in the Gulf of Alaska. A frontal system subsequently approached the California coast late on the 22nd with a low pressure center anchored off the central coast, and rain commenced falling in the San Francisco area about 0300 on the 23rd, continuing until 2100 with substantial amounts descending in the afternoon—total fall for the 23rd: 1.74″.

The Bay area received rains in the vicinity of 1.50″ as did points farther north. Inland at Sacramento the storm produced 1.28″, but amounts fell off sharply farther south in the San Joaquin Valley: Fresno .30″ and Bakersfield .33″. The middle coast, too, did not benefit greatly and much more rain was needed after the long dry spell.

Rainfall in the California Southland came mainly on the 24th with some light falls continuing on Christmas morning. Another low center associated with the frontal zone moved southeastward over the ocean to a position off San Diego. Barometers descended to low levels—Burbank's reading of 29.55″ marked a 30-year low for December. Though the amount of rain ran below the forecasters expectations, totals close to 1.00″ fell from Los Angeles southward to San Diego for the first real rainstorm since last April. Even inland at Las Vegas the catch measured 0.89″ on the 24–25th as moist Pacific air invaded the desert Southwest.

THREE DECEMBER STORMS—The first 20 days of December in the East produced little of note except for the unusual deepening of a secondary coastal low to pressures below 29.00″ on the 7th in the Hudson-Champlain Valley of New York and adjacent areas. But not until the Hudson Bay high appeared did any real wintry weather spread over the Northern States. Cold Arctic air masses accompanied the two Canadian highs with temperatures as low as −25° over interior Ontario and Quebec.

Along the southern border of the frigid air mass, a small low of innocuous appearance formed over Nebraska, moved east-southeastward to Kentucky on the 20th, gradually developing a circulation. Light snow spread from Iowa eastward across the upper Ohio Valley. Not until western Pennsylvania did any appreciable amounts fall, Pittsburgh 4″, with amounts increasing to 5–7″ at the coast of New Jersey. The storm center moved eastward offshore near Atlantic City. Washington, D. C. to the south receiving only a trace. The northern limit of appreciable snow was sharp along the Binghamton-Hartford-Providence line. Nantucket Island had 7″ (.54″ water), while Boston, just 90 miles to the north, received only 0.03″ precipitation and a trace of snow.

The storm, though not of great stature, brought the usual traffic disruptions and removal expenses to cities. Despite the inconveniences, the white mantle was welcomed by most since it provided much of the populous East with the first white Christmas in many years.

A second storm, also generated by the Hudson Bay high, was of completely different nature. A trough of low pressure moved across the northern and central Plains on the 21st–22nd with little temperature difference on either side and would not have amounted to much if it had not bucked against the high. With its eastward progress blocked, a circulation developed and precipitation commenced as moist air overran the shield of cold air to the east. The front edged eastward very slowly on the 22nd and 23rd and began to dissolve late on the 23rd over Illinois and Wisconsin, but the blocking had kept the precipitation process in action much longer than usual, resulting in heavy precipitation from northern Illinois into Wisconsin.

The cold easterly circulation crossing Lake Michigan picked up enough moisture to produce some unusual snow amounts in Wisconsin. Milwaukee's 11.3″ was a December record for 24-hour fall, and Madison's 9.3″ stood as the greatest December storm total in 50 years. It is interesting to note that Muskegon, almost directly east of Milwaukee but on the windward shore of Lake Michigan, had a snowfall of only 4.2″. In the same easterly circulation Duluth, at the western end of Lake Superior on the lee shore, had 11.2″ with areas only a few miles north or south receiving very little.

A third winter storm situation began to take shape over the Plains late on Christmas Day as the pressure trough which had caused the California rains pressed over the crest of the Rockies to form a definite cyclonic circulation over northeastern Colorado early on the 26th. The deepening over the central Plains occurred in conjunction with the rebuilding of the second Hudson Bay high. An unusual factor affecting the further development of the storm lay in the great mass of warm air which overrode the central Plains and middle Mississippi Valley. Temperatures on Christmas Day soared to the 50's as far north as South Dakota. At Sioux Falls it was the mildest Christmas on record. A definite warm front marked the advance of warm maritime air from the South; a mixture of rain, sleet, glaze, and snow fell to the north as the Hudson Bay high fed colder and colder air in. But to the south of the front which lay along the latitude of Chicago, the mercury at Omaha reached 60° on the 26th, 67° at Indianapolis and 71° at Huntington, W. Va., on the 27th; and 62° at Washington, D. C. on the 28th.

The storm's circulation attained its peak on the 28th with a central pressure of 987mb/29.19″ over Iowa while a 1040mb/30.70″ high stood over Hudson Bay, creating a very steep pressure gradient. Duluth at the western end of Lake Superior experienced a seiche as east-northeast gales pushed the water westward in a grand rush. For the 28th wind speeds at Duluth averaged 34 mph, with the fastest mile clocked at 49 mph—quite a breeze when combined with freezing rain and then four inches of snow!

Eastward across the Great Lakes and north of the warm front, freezing rain laid a heavy coat of glaze. This was particularly severe in western and central New York State: at Buffalo the weatherman called

it "the big ice storm" and at Rochester "about the worst on record."

Farther east it was a big snowstorm as the Hudson Bay high had manoeuvered into position to supply the necessary cold air—Albany 4″, Burlington 7″, Concord 11.6″, and Portland 13.6″. The heavier precipitation in the Northeast resulted from the formation of a secondary low on the warm front over Virginia and Maryland late on the 28th. The original center, now filling, drifted eastward from Illinois across the upper Ohio Valley on the 28–29th, joined to the active disturbance off the Atlantic Coast by a west-east trough whose presence kept the precipitation going over the Lower Lakes and Northeast until early on the 30th. The northeast storm did great damage on the New England coast on the 28–29th as tides approached record heights. Damage ran to several millions.

November (*Continued from page 33*)

from central Montana to Washington, where overrunning Pacific air contributed the moisture, did heavy general rains or snows develop.

The eastern ridge gave the streamlines of air flow a northeasterly twist over the Appalachians and Atlantic States, but the air contained in this flow was originally of polar or Arctic origin, though somewhat modified in its long transcontinental journey. Temperatures averaged below or near normal over the East except in the extremities: Cape Cod and Maine, the Outer Banks of North Carolina, and southern Florida. Pressure over all the western Atlantic Ocean averaged well above normal as another massive blocking anticyclone extended from central Greenland to the Bermuda area and then on to Spain without the intervention of a mean trough or front.

RECORD MID-NOVEMBER COLD WAVE—There were three distinct invasions of Arctic air masses into the United States during the first two weeks of November, each being record-breakers in some area for so early in the winter. On 3 November an Arctic anticyclone built up over the Yukon of Canada while a low pressure trough was sprawled along the northern U. S. border from Idaho to Lake Superior. Arctic air moved into Montana and adjacent states on the 4th and temperatures went below zero for the first time on the morning of the 5th (Cut Bank −8°).

The center of the anticyclone slide rapidly southward. On the morning of the 6th a large area of high pressure with readings above 1040 mb (30.72″) stretched from Utah to South Dakota and southward to northern Texas, new all-time November pressure maxima being reached in the latter. This dropped the cold air directly southward along the eastern slope of the Rockies and over the southern Plains. The zero line dipped into Nebraska (Valentine −1°); down to +10° in western Kansas (Goodland); and to +19° at Amarillo in northern Texas. Many points recorded the coldest for so early in the season—New Orleans' 34° on the 7th set an 88-year record.

Temperatures over the entire area rebounded quickly after this early blast as a complicated low pressure system moved into western Canada accompanied by mild Pacific air. Another Arctic anticyclone soon appeared over the Yukon on the 9th and by the 11th had built up a central pressure of 1053 mb (31.10″).

The second surge of Arctic air commenced to move southeastward on the 11th and crossed the Montana border early on the 12th, encouraged by low pressure developments to the south where a weak low, which had dwadled over Manitoba and Lake Superior, quickly developed great energy as the frigid air fed into the circulation to drop the central pressure to 984 mb (29.06″) over James Bay. Along the dividing line between the mild Pacific air over the American Northwest and the rush of Arctic air southward over the Canadian Prairie Provinces, an active front developed and blizzard conditions soon spread over western and central Montana. Helena had its greatest snowstorm since records were commenced there in 1870. From noon the 11th to noon the 12th, 21.5″ of new snow fell, a mark which exceeded the previous 24-hour fall for any day of any month by a full seven inches. The total fall of 21.7″ also made it the greatest single snowstorm in Helena's history, and the total November fall of 32.9″ broke the record for the month set back in 1896.

Early on the 12th the zero line crossed into Montana as the Hudson Bay low held its position and the mountain lows moved southeastward along the Great Divide. The intensity of this mid-November cold air mass had never been equaled in the 88 years of weather records in the area. On the morning of the 13th the mercury at Helena read −35° with even lower readings nearby: Lincoln −47° and Ovando −45°. The cold air then punged into the northern and central Plains where the morning of the 14th numerous early-season cold marks were smashed from South Dakota to Texas. Valentine, Nebraska, registered −22°. The zero line reached down to Kansas, crossed northern Missouri, and extended into central Iowa.

A second brief relaxation from the cold took place on the afternoon of the 14th and 15th as chinook winds brought mild air to the Plains—Valentine soared from −22° on the morning of the 14th to 47° on the 15th, but already a new surge from the North was entering the country. Another anticyclone had built up to 1050 mb (31.00″) on the 14th and 15th and dropped rapidly south-southeastward to southern British Columbia west of the Great Divide. New snows and new cold swept into the area already buffeted by early winter cold and snow. Again the mercury plunged to record November depths. Helena's newly-set all-time mark of the 14th was exceeded early on the morning of the 16th with −38.9°—a full ten degrees lower than ever registered in November prior to 1959. (The all-time low for any month at Helena is just −42°, reached in January of 1893 and 1957.) Very high barometric pressures were registered at the mountain stations of western Montana on the 16th—highest reported was Helena's 31.15″ at an elevation of 3893′.

The path of the high southward to British Columbia pushed cold Arctic air through the mountain passes into Washington and Oregon. On the morning of the 16th the mercury reached zero to +10° in eastern Washington and Oregon. By the morning of the 17th the vast anticyclone was centered in Kansas at 1045 mb (30.86″), and the cold air with freezing temperatures had penetrated all the way to the Gulf of Mexico: Mobile 26° and Galveston 29°.

As the anticyclone moved southward a quick temperature rebound followed. Helena reached +45° on the 19th, up 84 degrees from the low of the 16th. Out on the Plains Valentine soared from −10° on the 17th to 49° next day.

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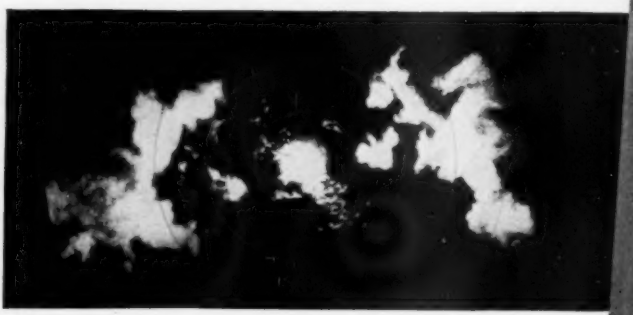

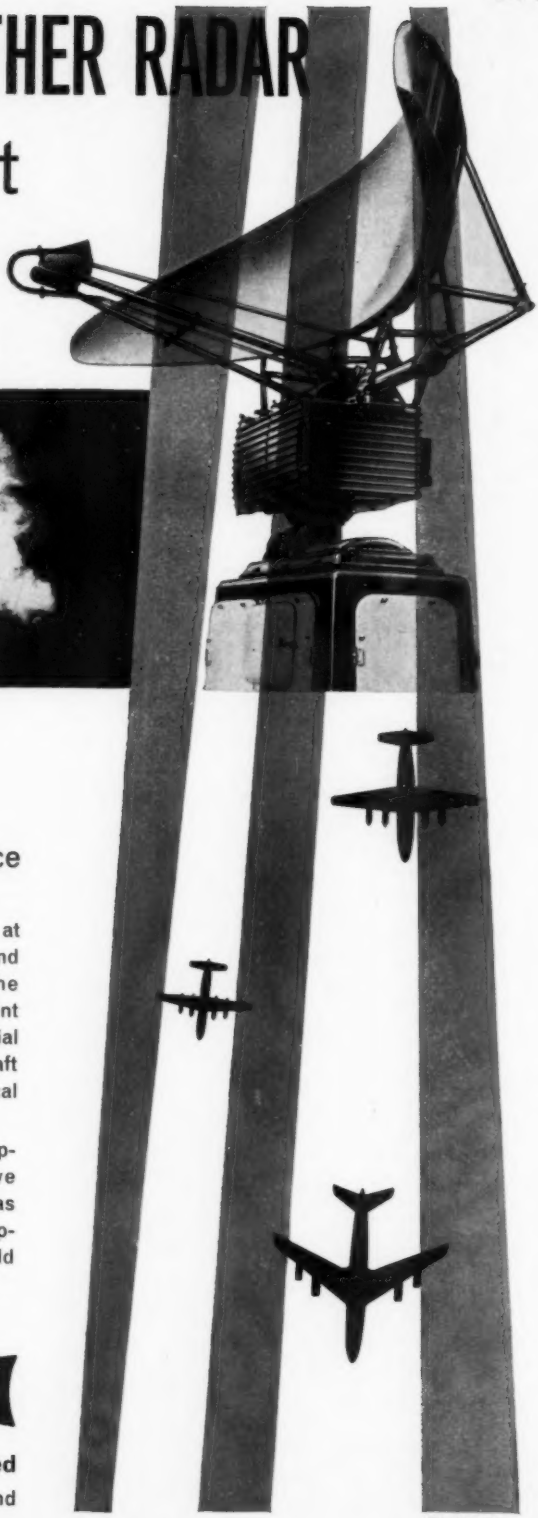

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Snow (*Continued from page 29*)

In particular, the industrial city of La Crosse, Wisconsin, on the Mississippi River, seemed to form the epi-center of the heavy snow belt. In February two severe storms swept across central Iowa, into extreme southeastern Minnesota, and across south-central Wisconsin. On both 10 and 22–23 February more than 10″ fell at La Crosse to make a February total of 31″. And unrelenting March produced three heavy snows as low pressure areas from the Southwest followed a track across Missouri and northern Illinois. Each time a belt to the northwest of the track, usually about 100 to 150 miles in width, combined the proper ingredients of available moisture and below-freezing temperatures to produce heavy snows.

The major storm of the winter struck the region already deeply encrusted in snow on 4–5 March. In eastern Iowa amounts measured up to 22.5″ (Fayette), in southeastern Minnesota 11″ (Winona), in northwestern Illinois 17″ (Galena), and 18.5″ at Wisconsin's La Crosse. Similar amounts fell across the interior of Wisconsin, raising snow cover to 30″ at many locations. Further additional falls followed throughout the cold month of March: La Crosse 7.8″ on the 15–16th, and 5.6″ on the 26th. The March total of 33.5″ boosted the seasonal catch to 78.3″, a new record for La Crosse where snow observations have been maintained since 1885.

Open Winter in the Rocky Mountains

The snow season in the Rockies made a promising start in November. In Montana several stations with long records reported their snowiest November such as Havre on the northern border with a total of 26.4″ in that usually dry region. Lander in west-central Wyoming received 26″ in a record early storm which gave a snow cover of 20″ on the 16th. This same disturbance reached far south to Tucson, Arizona, where an unprecedented fall of 6.4″ on the same 16th created a record for November and for any month in that sunny clime.

December and January proved dry months throughout most of the area. The only unusual snow situation again occurred in the south at Albuquerque in New Mexico where 14.2″ fell in 18 hours, an amount about twice the former 24-hour greatest fall. February's outstanding event came with a heavy snow of 15–30″ in the high San Juan basin of southern Colorado on 1–2 February which closed roads and passes, causing many accidents.

Eastern Colorado was the scene of some tough weather toward the end of March. On the 19–20th rain changed to snow, and the congealing mass clung to phone and power lines to create chaos there. On 24–26 March another wet snow of 10–20″ tied up northeastern Colorado east of the mountains. The same area again received another blow from the Snowman on 7–11 April when 20–30″ of wet snow dropped on the area with blizzard conditions developing out on the Plains. Denver was on the border of this snow activity yet received very heavy late season falls: March 26.8″ and April 17.6″ to approach records for those months. A final visitation of winter struck in south-central Montana on 15–16 April when a wet snow accumulated on wires to a thickness of 1–2″ and caused phone and power failures.

The Pacific Slope

After two years of more than adequate precipitation, the season of 1958–59 fell far below normal expectations. At the close of the snow season on May 1st only the Columbia basin and Washington coastal area could look forward to normal stream flow from melting snow. In southern Oregon, California, and the Plateau States the situation appeared critical as the long dry season opened. Only the storage reservoirs from the previous season's great surplus saved the situation.

The winter season in California opened with a severe storm on the 14–15th which caused snow down to low levels. Near-blizzard conditions existed in the southern Sierras as gales whipped the snow around, though the greatest fall measured only 12″ at Squaw Valley Lodge (6226′). The remainder of November and the entire month of December, however, produced very little. The largest December total turned in was only 21″ at Twin Lakes!

A major storm swept all California on 4–5 January and deposited the first good amounts in the mountains. Mt. Shasta Ski Bowl, a new snow-reporting station at 7841′, increased its cover from 10″ on the 4th to 109″ on the 11th. At Squaw Valley 27″ fell on the 5–6th,

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but this melted by the 13th and the ground was bare until the 25th. The figures at Squaw Valley are of interest because the Winter Olympics are now being staged there.

A snowy February raised Californians' hopes that the flakes would now arrive in the necessary quantity to save the situation. At Mt. Shasta City, an old Weather Bureau location at 3544′, the February total of 73.2″ was the greatest for that month since 1918. A fall of 105″ at Blue Canyon set a new February mark as did the 24-hour fall of 33″ on the 10–11th. The Mt. Shasta Ski Bowl had a big snow time on 14–18 February when 198″ fell in the 5-day period, raising the ground cover to 247″. Squaw Valley received its first skiing snow on 10–11 February with 65″ to make a good 50″ base around the Lodge—February's 114″ total was the only month to produce a significant amount. February, to all economic purposes, ended the snow season in California with the result that the runoff fell far below needs and was reminiscent of the dry years in the 1930's.

Up in Oregon Crater Lake, the snowiest reporting station in that state, had a seasonal total of 387″, about half of what would fall in a big year, and no month topped the 100″-mark, a very unusual circumstance at the 6475′ exposure.

In the State of Washington cyclonic activity was frequent all winter so snow came in sufficient quantities for all purposes. At Paradise Ranger Station on Mt. Rainier (5550′) four winter months had totals of more than 100″—the season's figure was 646″. And Stevens Pass at 4085′ turned in 623″.

Circulation (*Continued from page 14*)

subnormal in much if the area west of the Continental Divide under the influence of sharp anticyclonic curvature and dry northerly winds at 700-mb (fig. 8). San Francisco, Calif., had 73 consecutive days without measurable rain.

Shortly after the middle of November the planetary wave train shown in figure 8 began to move eastward and diminish in amplitude. Increased westerlies produced foehn warming, first in Montana, and then progressively farther east and south. This trend continued into December, which was dominated by a

typically high index circulation, with mild Pacific air masses over most of the United States.

California Warmth

One of the most persistent features of the year as a whole was abnormal warmth in coastal California. In much of this region surface temperatures averaged above the 1921–1950 normal during each month of the year. At San Diego monthly mean temperatures during 1959 were the highest on record during March, April, July, and November. A similar statement applies at Los Angeles during April, June, and July, and at San Francisco airport during March, April, and August. The warm regime actually began a few years ago, and temperatures have exceeded normal every month since April 1956 at the International Airport in Los Angeles. The complete explanation of this long-period climatic fluctuation is too complex to be discussed in this review.

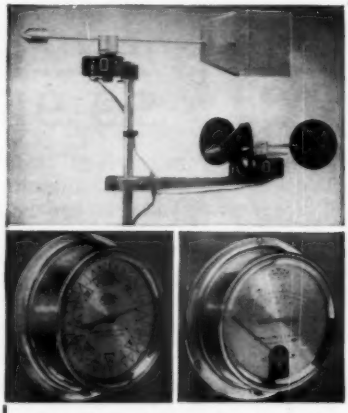
* Further details of the weather and circulation of each month can be found in the following publications of the U. S. Weather Bureau: *Monthly Weather Review, Climatological Data—National Summary,* and *Weekly Weather and Crop Bulletin.*

RADIO AND TV SEAL OF APPROVAL

The AMS has instituted a Seal of Approval program for radio and TV weathermen. The object is to recognize competence in weathercasting and to maintain a high standard of professional conduct in this sphere of communications. Fifteen seals of approval were presented at the 40th Anniversary Business Meeting by Prof. Kenneth H. Jehn, chairman of the AMS Board on Radio and Television Weathercasting.

The specific criteria upon which program ratings are made in reviewing professional members' applications for the Seal of Approval are: (1) informational value, (2) audience interest, (3) educational value, and (4) professional attitude.

Three previous awards have been made recently to professional members of the AMS, and a number of applications are now before the board for review. The Society's professional members within the local area of the applicant in addition to the Board members participate in the rating procedures of an applicant's weather program.



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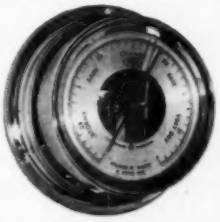

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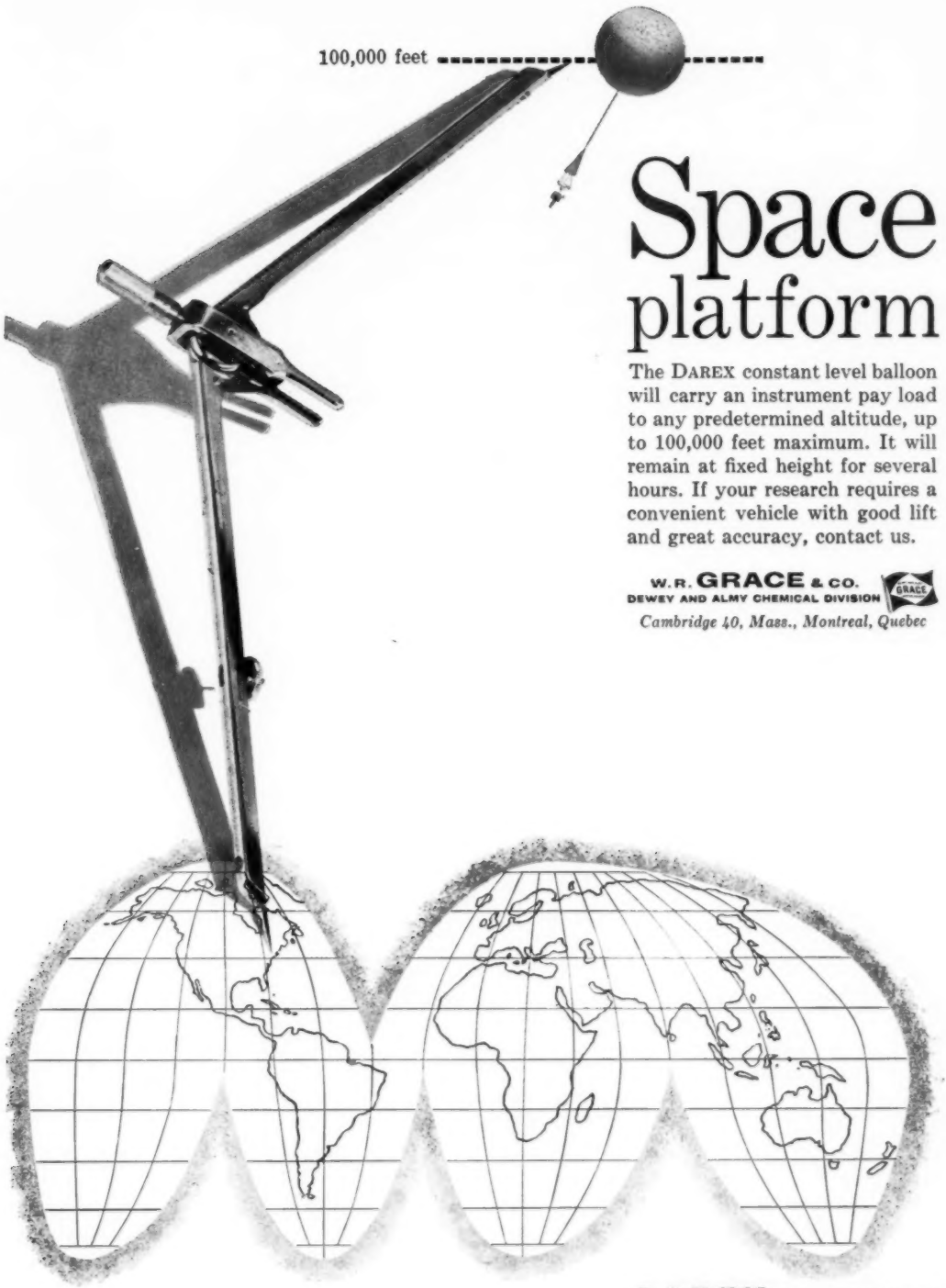

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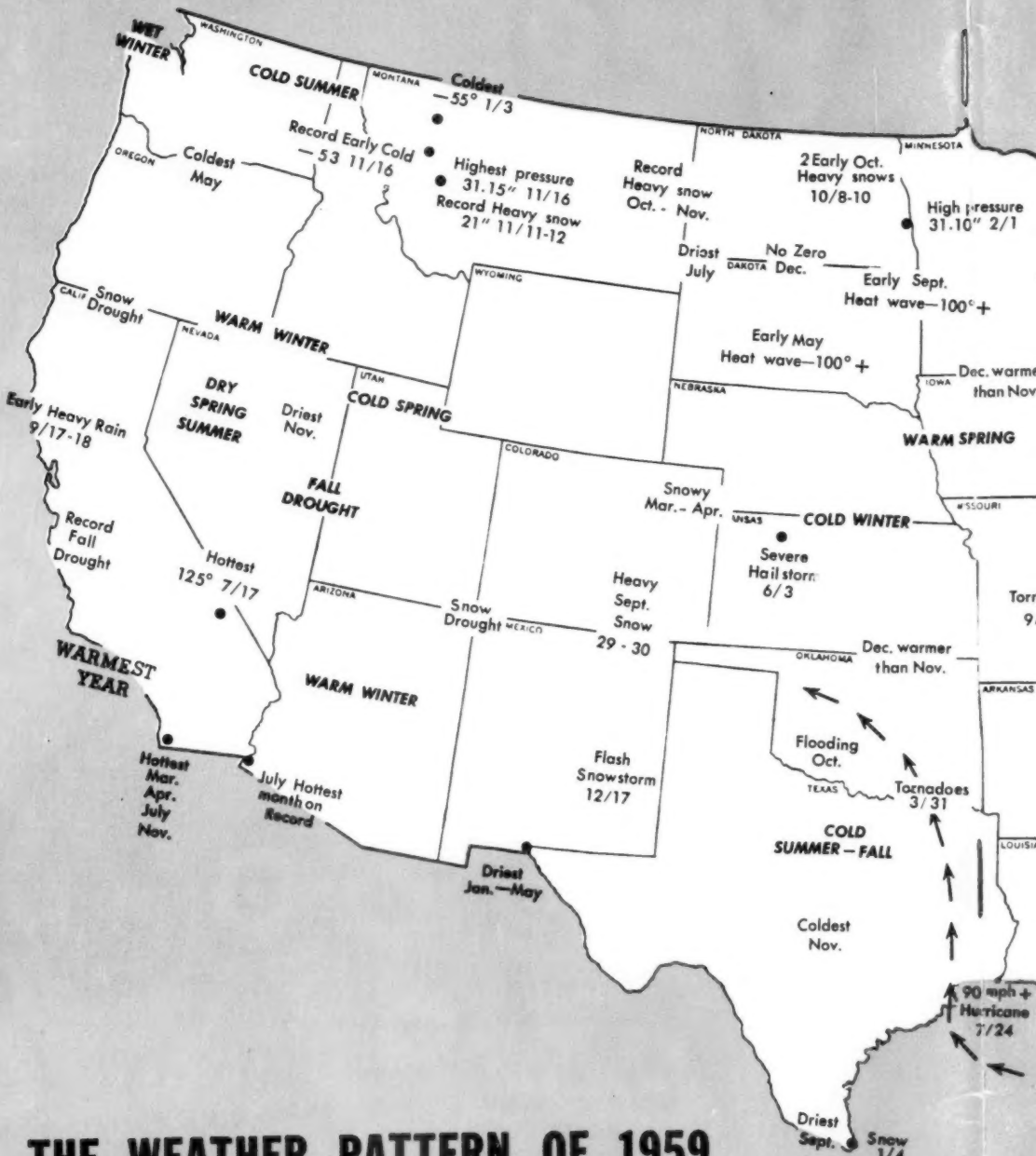

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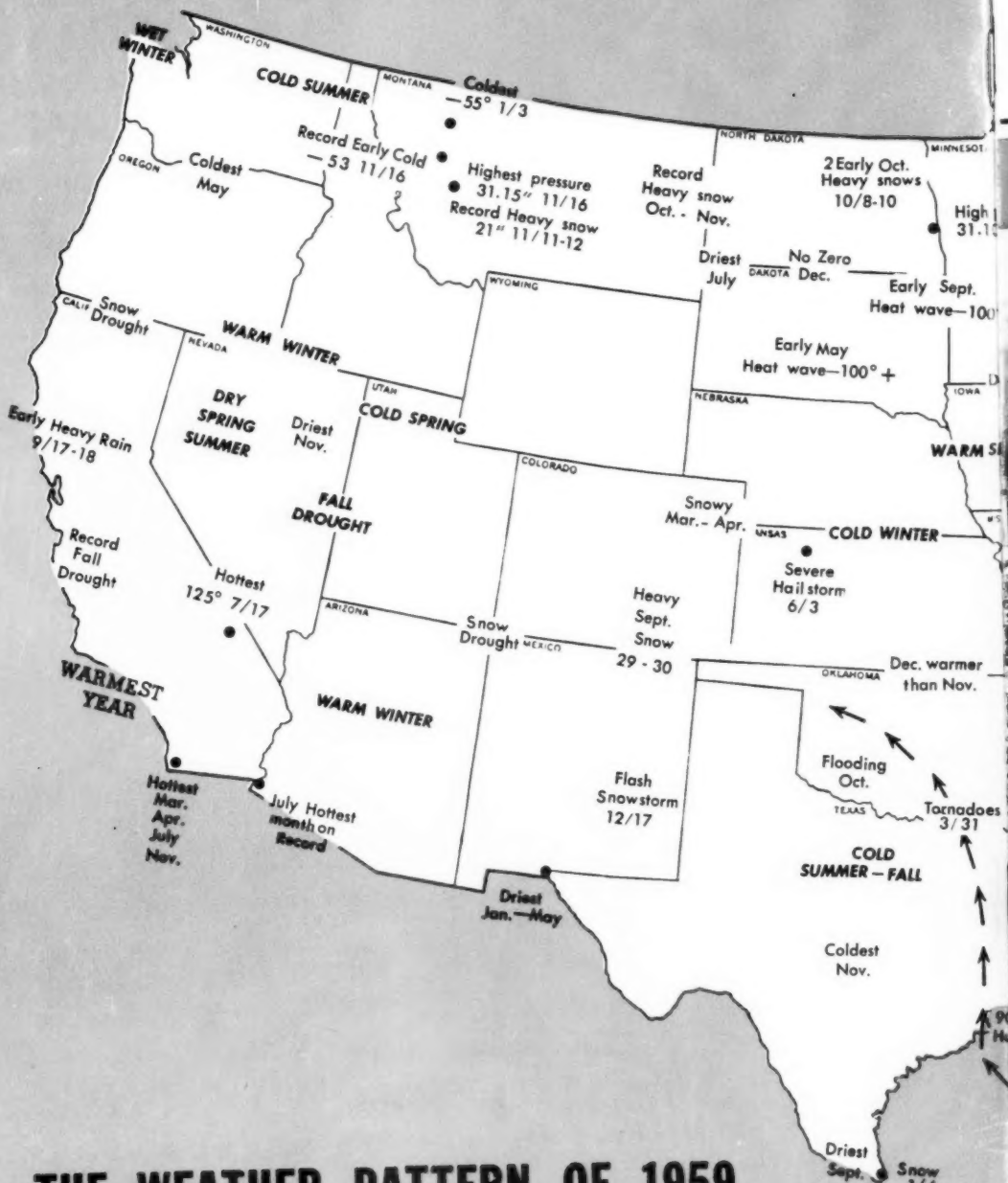

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